RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXI.

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ADDITIONS TO THE LIBRARY.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part I.] 1888. [February.

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1887.

Personnel of Survey and General Distribution.—On taking over the Directorship of the Survey in April last from Mr. Medlicott, I found the Staff of the Survey still below the normal number, owing to vacancies a long time unfilled; or under its effective strength through some of the officers being detached on special work.

The distribution over so vast an area as the Indian Empire, was as follows:—

Mr. Foote, on special deputation to the Mysore Government.
,, Mallet, Museum and Laboratory.
,, Hughes, special deputation with the Deccan Company, Hyderabad.
,, Fedden, Vizagapatam.
,, Hacket, Rajputana.
,, Griesbach, just returned from Afghan Boundary Commission.
,, Oldham, Salt Range.
,, Bose, Chhattisgarh.
,, La Touche, Assam.
,, Middlemiss, Himalayas.
,, Jones, Upper Burma.

Except from Mr. Hughes, who does not furnish us with any reports, satisfactory, and in some cases important, work has been carried out by all the officers named, though it has been of too detached a character to make any particular show in the progress map appended to this report.

Two of the vacancies have since been filled up in the appointment of Dr. Fritz Nöetling (Berlin University) as Palæontologist, and of Mr. Philip Lake (Cantab.) as Assistant Superintendent.

Mr. Mallet is again absent on sick certificate from 26th June for one year; Mr. Jones officiating for him as Curator and in charge of the Laboratory, though he is ready at the same time for any special and short field exploration. Mr. Hughes' deputation with the Deccan Company will not cease until 15th May 1888: and the

placing of Mr. C. L. Griesbach's services at the disposal of the Foreign Office for employment as Geologist to His Highness the Amir of Afghanistan for two years has just been sanctioned.

Perhaps for the first time, so large an indent has been made on us by Native States for deputation on special enquiries, a diversion from the proper work of the Survey which can hardly be avoided, although the officers can be ill-spared where so much having an economic value has yet to be worked out in the geological formations, the limits or relations of which are being systematically followed out. It is a distinction also, that the services of Mr. Foote and Mr. Hughes should have been specially asked for by the Mysore Durbar, and the Deccan Company respectively; while it is eminently satisfactory that their services have been, and are, appreciated. Mr. Foote has completed his deputation; but a still further call has been made on us by the Kashmir Government, and for this duty Mr. La Touche was selected.

The sudden death of Mr. Francis Fedden at Vizagapatam, on the 27th December last, has deprived us of one of our oldest colleagues, who had only just attained the long-waited-for promotion to the 1st grade.

The progress and occupation of the Survey has been in the following order:—

SOUTH INDIA.
Mr. Foote.
Mr. Fedden.
Mr. Lake.

Peninsular Region.—Mr. Foote has the Madras Presidency with its immense area of the crystalline rocks, or gneisses, among which, however, he is still carrying out his latest distinction of a newer (Dharwar) series. At present the great interest attaching to this series of transition rocks is not so much that it may fall in with, or represent, some or all of the various transitional formations of Central India, which have been treated of by so many of us under the names of Bijawars, Aravalis, Champanirs, and Chilpis: but that it is the series in which auriferous reefs are more particularly developed in the Madras Presidency. I, myself, having had to work out the auriferous rocks of the Wainád region, which certainly appeared to me to occur among bands of the older gneisses, am unable to follow Mr. Foote throughout the whole of his generalizations, which would seem to tend towards an extension of the Dharwars into Wainád; but the fact still remains that he is perfectly clear as to the Mysore country to which his attention has been more thoroughly devoted. In this way he has become the best gold man we have; not an expert in the common acceptation of the term, which is properly a man capable of exploiting a region where gold is known to exist in greater or less quantity, but a geologist, experienced, *par excellence*, in the kind of rocks, or the particular formation likely to be auriferous in India.

Mysore and Bellary country: Dharwar series; auriferous.

The result of his deputation to the Mysore Government has been a lengthy report, founded on an extremely rapid tour over the very large area exhibiting gold indications in that State. I cannot but express regret that the time at Mr. Foote's disposal for examining such a large tract of country was all too small for the questions or the interests involved. His examination, such as it was, stands however, as the most reliable and scientific record of the auriferous veins of the country. To a very large class of men interested honestly in the occurrence of gold in Mysore, Mr. Foote's report is no doubt disappointing, because it fails to paint in glowing colours tracts of quartz reefs, or areas of gold washings which they believed, or had been persuaded to

believe were promising; or that it shows that the evidences he considers hopeful in other tracts were not thought worth other than passing examination by previous explorers. This is only in the nature of such an investigation, more especially since the deputation was to report on the auriferous tracts already visited by Messrs. Lavelle and Marsh in the previous year. Mr. Lavelle was the pioneer of the Kolar workings, and, what is far more to the point, a most successful pioneer. Mr. Foote's report was not suitable to these Records, but its material will be embodied in a paper shortly to be published.

Mr. Philip Lake, the junior Assistant Superintendent, has been placed under Mr. Foote's charge for the present; and it is pleasant to hear that there is much promise of the Survey having again gained by the judicious scheme of selection in the recruiting of our staff, introduced and most strictly watched by my predecessor Mr. Medlicott.

VIZAGAPATAM.

Mr. Fedden, who was transferred to the Madras Presidency at the end of 1886, took up work in the Vizagapatam District, an endeavour thus being made to fill in the large unsurveyed gap between the Godavery and the Ganjam Districts in the Northern Circars, and he had been going on steadily with his survey, but so far without finding anything of particular interest. His untimely death has practically stopped any chance of this district being further examined during the present season.

CENTRAL PROVINCES.
Self.
Mr. Bose.
Sub-Asst. Kishen Singh.
,, Hira Lall.

My executive work closed with my boring experiences in the Chhattisgarh Coal-fields, the results of which are given in the concluding part of the last volume of the Records. These results show practically that throughout the whole area, as far as it is convenient to the trace of the Nagpur-Bengal Railway, there is only one tract near Korba which has shewn itself, by the borings, at all worthy of consideration as a likely place for workable coal of good quality. The credit of this find, which though it be among coal measures already known, is due to Sub-Assistant Hira Lal, who so far, and in this way, has done credit to the grand training he had under Mr. Hughes. A single boring, at the end of the season, when of course work could not be finished, has proved that this coal of Gordhewa does not change for the worse to the deep, as has unfortunately been the case with nearly all the other borings in other parts of the area.

CHHATTISGARH COAL-FIELDS.

I could not but marvel at this disparity between boring and outcrop samples, which certainly seemed to show that the boring samples might not be so free from admixture with shales as one is generally led to expect in work of this kind. Under these circumstances, and considering the interests involved, I have felt bound to recommend small trial pits as the readiest method—in the difficulty of getting improved boring plant or trustworthy workmen—for ascertaining the quality of the coal in bulk. Such pits are to be tried near Hingir, and at Korba; and further borings should be put down on Hira Lal's seam at Gordhewa to ascertain the area of that field.

TRANSITIONS AND VINDHYANS.
Mr. Bose.

In the early part of the season I devoted some time to the western edge of the great Chhattisgarh basin, where Mr. Bose had worked in previous seasons among the Vindhyans and Chilpis, though he had then failed to satisfy Mr. Medlicott or myself as to his

capabilities for distinguishing these two series in detail, or for the reporting on or mapping of them. However much he may have failed to satisfy us in this way, it is necessary to state that he did, after all, recognize an unconformity between the two; and under very exceptional conditions of stratigraphy. Mr. Bose was to have continued the work in this region; but even from here it has been necessary to move him, to more urgent, and as it turns out very interesting work, at the manganese ores near Gosalpur in the Jubbulpore district.

The Manganese ores of the Jubbulpore District.

I have just returned from an inspection of Mr. Bose's work as far as it has gone, he having brought features in the distribution and mode of occurrence of these ores to notice, which required testing in a more authoritative way than usual, owing to the ground having been previously visited by Messrs. Medlicott and Mallet. I was greatly pleased to find that Mr. Bose was not only doing his work well and carefully, but that he had made observations and recognized features which will lead to a more qualified view of the manganese ore capabilities, as well as towards a further elucidation of the origin of that form of decayed, or methylosed rock, so well known as laterite.

Work of Sub-Assistants.

Messrs. Kishen Singh and Hira Lal were engaged during the last season, the one about Mandla and Seoni in the Central Provinces, and the other among the coal-fields in Chhattisgarh; that is, each of these Sub-Assistants is following up the areas or boundaries of formations already ascertained by the executive officers of the Survey. It is necessary to mention this, because, unhappily, Babu Kishen Singh has got it into his head that he is now on independent work, and so fit for promotion. It may be as well to state at once that this is not the case; as yet, he is certainly not fit to be set on new and independent work. This is however quite a different matter to the doing of the work he has in hand, which I am only too glad to praise as well and carefully executed. At the same time I should wish, as soon as the time may come round, to recommend that he, as well as Mr. Hira Lal, should be better remunerated for their work: this has already been strongly advocated by my predecessor, and at the first opportunity I shall press it again.

Mr. Hira Lal has the luck to be working at the coal-bearing rocks, and I think I have sufficiently expressed my liking for him and his work in that connection in my last paper on the Chhattisgarh coal-fields.

Both Sub-Assistants have sent in their maps, accompanied by fairly interesting and readable progress reports.

CENTRAL INDIA.
Mr. Hacket.
Mr. R. D. Oldham.

Rajputana has been for many years Mr Hacket's area, and he is still in it, working out details of the very puzzling and complicated relations of the several series or groups of transition rocks. Up to the close of last season his work lay in the neighbourhood of Mount Abu; but we are hopeful that his investigations may extend more to the westward, where he may be able to touch on the more economically interesting Gondwanas, with their coal possibilities.

As stated in Mr. Medlicott's last annual report, Mr. Oldham was occupied in testing his own suggestion of a possible occurrence of coal measures with coal in Jessalmer, though he was not very sanguine of success. It was, indeed, more of a scientific generalization than a suggestion, and hopes were high that success might

attend it; but so far the promise is not good, as will be seen in the memorandum published in the present number of the Records.

Extra Peninsular India.—Early last year, further evidence was sent in by Dr. H. Warth on the identity of the '*Olive Shales*' and '*Speckled Sandstones*' in the Salt Range geology. Mr. Oldham having been sent up in the previous season to settle the question, he was again despatched to the Salt Range to verify Dr. Warth's observations, which were published in the May part of last year's Records. The groups of rocks with boulder-beds at their bases, which have hitherto, in the eastern and western portions of the range, been considered, respectively, the one as of cretaceous, and the other as of upper palæozoic age, will now be merged in the name '*Speckled Sandstone*,' this group being, according to the latest utterance of Dr. Waagen, of the age of the upper coal-measures.

Mr. Oldham.
Dr. H. Warth.

Having finished his work in the Salt Range, which also included a visit to the Dandot Coal Mining operations, Mr. Oldham then proceeded to Simla, preparatory to making an expedition to Ladak and back by Kashmir, according to the desire of my predecessor, with a view to determining how far the discrepancies between the sequence of beds in Kashmir, as described by Mr. Lydekker, and that of the Simla region were real. On return from other work early in November, he was deputed to look up the prospects of obtaining petroleum at Tijarah, near Ulwar. His report confirms our original examination, *viz.*, that the bituminous stuff obtained from Tijarah is merely an occurrence of combustible organic matter in a thin layer, or seam, associated with potsherds and other refuse formed on the site of an old cattle village.

HIMALAYAS.
Mr. Oldham.
Mr. Middlemiss.

Mr. Middlemiss has been steadily pursuing his proper work in the lower Himalaya about British Garhwal and Kumaun, the results of which he is giving in a series of papers in the Records. His work continues to be excellent, and there is no lack in his enthusiasm and energy.

The Kashmir Government having applied for a geologist to look up and report on the occurrence and possible exploitation of the sapphires in the Zanskar district, Mr. La Touche was detached from his recess work in Assam. He was only able to work for a month at the locality, which lies just below the snow line, mainly driving an adit, or cutting through the great mass of débris which had fallen down over the old diggings, though without reaching the sapphire rock, and thus the examination is yet incomplete. Waiting a better opportunity for re-exploration when the retreat of the snow will permit, his services have been very advantageously employed by the Durbar in examining the Jummu coal, originally discovered by Mr. Medlicott, on which he is inclined to look hopefully, provided some method can be devised, similar to that adopted in Italy, for compressing the unfortunately crushed and powdery fuel into bricks.

KASHMIR.
Mr. LaTouche.

Sapphires.

Jummu Coal.

Mr. E. J. Jones was fully occupied until the end of the season in examining the principal coal-fields in Upper Burma, as well as the metalliferous mines in the Shan Hills, reports on which appeared in the last number of the Records.

UPPER BURMA.
Mr. Jones.

Memoirs, Records, Palæontologia Indica, Manual.

Survey Publications.—Part I, of the twenty-fourth Volume of the Memoirs, *viz.* :—"Southern coal-fields of the Satpura Gondwana Basin," E. J. Jones, was issued early last year : it treats of what is more generally known as the Chindwara coal-field. Volume XX. of the Records contains twenty-three papers, besides other matter, four of the articles being of important economic value. In series X, Vol. IV, Part III, of the Palæontologia Indica, Mr. R. Lydekker has described the "Eocene Chelonia from the Salt Range." It was to have been expected that the concluding part of Dr. W. Waagen's great volume on the fossils of the Productus Limestone of the Salt Range would have been issued, but an unforeseen delay has occurred through the copies of the last three plates, which were despatched from Munich long ago, having been mislaid in the carrying agent's office. Part IV, "Mineralogy," of the Manual of the Geology of India, by F. R. Mallet, was issued in July last : it forms a very fitting completion of the Manual.

Library.—Two thousand and twenty-four volumes, or parts of volumes, were added during the year; 1,270 by presentation or exchange, and 754 by purchase.

Museum.—Now that we have once more a Palæontologist on the Survey in the person of Dr. Fritz Nöetling, an endeavour is being made to bring the collections sent in from the field under thorough examination; particularly the *invertebrata*, which have in great part lain by so long, owing to the pressing necessity during Dr. Feistmantel's time for treatment of the flora of the Gondwana Formation, the lower division of which, it is perhaps hardly necessary now to mention, includes the Indian coal measures. Up to this time, Dr. Nöetling has been engaged in working out the *ammonitidæ* collected by Mr. P. N. Bose in the Bág beds of the Narbada valley, which, I am informed, corroborate in every way the original conclusions of Professor P. Martin Duncan regarding the Cenomanian age of these beds. The Silurian and other fossils, to be referred to in Mr. Griesbach's forthcoming Himalayan Memoir, are also being examined.

The Geological and Mineralogical galleries are in perfect order, the collections being gradually added to by presentations or by exchange with American, Continental, and British Societies and Collectors, notices of which have appeared in each part of the last volume of the Records.

Tours of the Director.—Notwithstanding the inconveniences referred to from time to time in his Annual Reports by my predecessor, among which are the having to rely on the carrying on of the current duties of the office by any Geologist who may be at hand, instead of a special Assistant as is the case with other Departments, and the editing of the publications of the Survey; I have been able to make three short tours. These were to the crushed-coal outcrops near Teendaria in the Darjeeling District; to the Karharbari coal-field; and to the Manganese ore deposits near Jubbulpore, the need for an authoritative visit to which I have already indicated when referring to Mr. Bose's work there.

WM. KING,

Director of the Geological Survey of India.

CALCUTTA,
The 31st January 1888.

List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India, during the year 1887.

ADELAIDE.—Royal Society of South Australia.
BALTIMORE.—Johns Hopkins University.
BASEL.—Natural History Society.
,, Basel University.
BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
,, Royal Prussian Academy of Science.
BOLOGNA.—Royal Academy of Sciences.
BOMBAY.—Bombay Branch, Royal Asiatic Society.
,, Marine Survey of India.
,, Meteorological Department.
,, Natural History Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
,, Society of Natural History.
BRESLAU.—Silesian Society.
BRISBANE.—Queensland Branch, Royal Geographical Society of Australasia.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Royal Academy of Sciences, Belgium.
,, Royal Geographical Society of Belgium.
,, Royal Malacological Society of Belgium.
,, Royal Museum of Natural History, Belgium.
BUDAPEST.—Hungarian Geological Society.
,, Hungarian National Museum.
,, Royal Geological Institute, Hungary.
BUENOS AIRES.—National Academy of Sciences, Cordoba.
BUFFALO.—Society of Natural Sciences.
CALCUTTA.—Agricultural and Horticultural Society.
,, Asiatic Society of Bengal.
,, Editor, Indian Engineer.
,, Editor, Indian Engineering.
,, Meteorological Department, Government of India.
,, Royal Botanic Garden.
,, Survey of India.
,, The Calcutta University.
CAMBRIDGE.—Philosophical Society.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CASSEL.—Verein fur Naturkunde.

CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Royal Danish Academy.
DEHRA DUN.—Great Trigonometrical Survey.
„ Forest Department.
DELFT.—Polytechnic School.
DRESDEN.—Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
„ Royal Dublin Society.
„ Royal Irish Academy.
EDINBURGH.—Geological Society.
„ Royal Scottish Society of Arts.
„ Scottish Geographical Society.
GLASGOW.—Geological Society.
„ Glasgow University.
„ Philosophical Society.
GÖTTINGEN.—Royal Society.
GRANVILLE.—Denison University.
HALLE.—Kais. Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.
„ Natural History Society.
HARRISBURG.—Second Geological Survey of Pennsylvania.
HOBART.—Royal Society of Tasmania.
KÖNIGSBERG.—Physikalisch-Okonomische Gesellschaft.
LAUSANNE.—Vandois Society of Natural Sciences.
LEIPZIG.—Geographical Society.
LIÉGE.—Geological Society of Belgium.
LILLE.—Société Géologique du Nord.
LISBON.—Geological Commission of Portugal.
LIVERPOOL.—Geological Society.
„ Literary and Philosophical Society.
LONDON.—British Museum.
„ Geological Society.
„ Iron and Steel Institute.
„ Linnean Society.
„ Royal Asiatic Society of Great Britain and Ireland.
„ Royal Geographical Society.
„ Royal Institute of Great Britain.
„ Royal Society.
„ Society of Arts.
„ Zoological Society.
LYONS.—Museum of Natural History.
MADRAS.—Literary Society.
„ Meteorological Department, Government of Madras.

MADRID.—Geographical Society.
„ Royal Academy of Sciences.
MANCHESTER.—Geological Society.
MELBOURNE.—Department of Mines and Water-supply, Victoria.
„ Geological Society of Australasia.
„ Royal Society of Victoria.
MILAN.—Royal Institute of Science, Lombardy.
„ Society of Natural Science.
MONTREAL.—Geological and Natural History Survey of Canada.
„ Royal Society of Canada.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Royal Bavarian Academy.
NAPLES.—Academy of Science.
NEUCHATEL.—Society of Natural Sciences.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
„ The Editors of the "American Journal of Science."
NEW YORK.—Academy of Sciences.
PARIS.—Geographical Society.
„ Geological Society of France.
„ Institute of France.
„ Mining Department.
„ Société Académique Indo-Chinoise de France.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
„ Wagner Free Institute of Science.
PISA.—Society of Natural Sciences, Tuscany.
ROME.—Royal Geological Commission of Italy.
„ Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
ST. PETERSBURG.—Geological Commission of the Russian Empire.
„ Imperial Academy of Sciences.
SACRAMENTO.—California State Mining Bureau.
SALEM, MASS.—American Association for the Advancement of Science.
„ Essex Institute.
„ Peabody Academy.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
SYDNEY.—Australian Museum.
„ Department of Mines, New South Wales.
„ Linnean Society of New South Wales.
„ Royal Society of New South Wales.
TORONTO.—Canadian Institute.

TURIN.—Royal Academy of Sciences.
VENICE.—Royal Institute of Science.
VIENNA.—Imperial Academy of Sciences.
„ Imperial Geological Institute.
„ Imperial Natural History Museum.
WASHINGTON.—Director of the Mint.
„ Philosophical Society.
„ National Academy of Sciences.
„ Smithsonian Institution
„ United States Geological Survey.
„ United States War Department.
WELLINGTON.—Colonial Museum.
„ Department of Mines, New Zealand.
„ New Zealand Institute.
„ Surveyor General, New Zealand.
YOKOHAMA.—Asiatic Society of Japan.
„ German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Natural History Society.

The Secretary of State for India.
The Governments of Bengal, Bombay, India, Madras, North-Western Provinces and Oudh, and the Punjab.
Chief Commissioners of Assam, Burma, and Central Provinces.
The Commissioner of Northern India Salt Revenue.
The Resident at Hyderabad.
The Surgeon-General, India.
The Quarter-Master-General of India, Intelligence Branch, Simla.
Foreign, Home, Public Works, and Revenue and Agricultural Departments.

Number of volumes and parts presented during 1887	1,270
Ditto purchased do. . . .	754
Total .	2,024

Crystalline *and* Metamorphic Rocks *of the* Lower Himalaya, Garhwal, *and* Kumaon, Section III, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*—(With 3 plates.)

PART I.

BASIC LAVAS NORTH OF DUDATOLI.

In due order I must now sketch in brief outline some basic lavas and associated rocks which lie to the north of the Dudatoli area, and which occupy a large portion of the Syoons of Dhanpur, Ranigadh, Tili-Chandpur, Chandpur, and Nagpur Tala. As in the case of the acid lavas of Lobah, but little petrological work can be done in the field without the aid of the microscope to determine, in the first instance, what is the intimate structure of these, to the eye, absolutely compact and enigmatical rocks. It will therefore be necessary to follow the plan adopted in my last paper of very briefly describing the extension, lie, and general habit of the rocks as a whole, giving the results of the examination of numerous microscope slides in more detail. The whole of these notes will then form a body of data which will be a useful preliminary to the final description of the fully mapped area.

Like the ancient rhyolites of Lobah, these basic rocks belong to a geological system distinctly newer than the schists among which the gneissose-granite of Dudatoli is insinuated. The fault which separates the older and the newer series near Lobah, in its curve round the north portion of the Dudatoli area, similarly divides the rocks about to be described from the older Dudatoli schists. The discordancy in the dips, and in the nature of the rocks on each side of the faulted boundary, give it a great structural importance, and make it a striking feature both in the field and on the map. Its great extension, running as it does for 30 miles at least, proclaims it at once as a master-fault that has had no little influence in determining the present geology of this part of Garhwal. On its south side it leaves exposed the elongated quaquaversal synclinal of the Dudatoli schists, a long flat synclinal of great regularity—an oasis as I have previously termed it—among much more disturbed and highly tilted rocks, on to which we step when the faulted boundary is crossed. These newer lavas and other stratified deposits dip *away* from the Dudatoli centre in quite as marked a manner as the older schists dip *towards* that centre; and being only at present known on the north, north-east, and east sides of the older schistose area, they therefore form the north-east half of a quaquaversal anticlinal elongated in a direction north-west and south-east, and which, if completed, would cover in the whole of the present Dudatoli area, that is to say the ground represented on the map facing page 142, Vol. XX of this publication.

I must again refer the reader to that map, not for the purpose of giving at present a detailed description of the stratigraphy, but in order to roughly indicate the general positions of the rocks now to be discussed, and to give a connection, however superficial, between these notes and Sections I and II of this series. A few miles to the north beyond the limits of the map, but contained in sheet 14 of the 1 inch scale, from which the map is taken, the higher parts of the Dobri-Pandubni ridge are occupied by a massive limestone, an undoubted portion of the same rock as was des-

cribed in the Lobah area.[1] Only a small crescent of outcrop with the concave side towards the south has escaped the fault, but there is sufficient to shew that it overlies a purple and grey slate series with a suspicion of volcanic breccia among it closely resembling the purple slate and volcanic breccia series found in west Garhwal nearer the plains.[2] The horns of the crescent abut against the great fault, and outward from these points we travel over an ascending series of the volcanic rocks consisting chiefly of basic lavas and associated quartzites. Above the west-north-west horn, however, there is about a square mile of outcrop of the acid lava alluded to in my last paper and described microscopically by reference to a specimen, No. $\frac{7}{780}$, from the head of the stream running by Peera. Above it come the more basic lavas by gradual interbedding with, at first, a very large thickness of sedimentary rocks, *viz.*, purple and white quartzites and conglomeratic quartzites. Although the sequence here shews unmistakably the connection subsisting between the two volcanic series, and between those series and the massive limestone, yet it is complicated to a small extent by an inversion of the whole, so that the apparent dip in this one corner of the district is towards the south-south-east instead of in the opposite direction. This inversion is rapidly resolved within a radius of a few miles; as a traverse along the ridge towards Charmarguri trigonometrical station makes very evident: the purple quartzites and coarse grits rise more and more to the vertical and then fall again, but with an exceedingly high dip towards the north-north-west. They eventually settle down to a dip of about 70° in that direction. The limestone at Dobri and Pandubri trigonometrical stations is devoid of this complication: the angles are steep, sometimes even approaching 80°, but the dip, both of the limestone and of the superposed basic lavas and quartzites, is steadily towards the north. The intervening rhyolites are absent round the crescent of limestone in this neighbourhood, and they do not again make their appearance until Lobah itself is reached.

With dips radiating between the north-west and north-east, usually steep, but more so near the Ganges towards the north-west than along the Pindar river and round about Chandpur Garhi, these beds continue over the large area enumerated in the beginning of this note. The dip is, however, in many isolated cases in an opposite direction, and the same beds often seem to be repeated, either by faulting or by sharp flexure; so that there may not be such an immense thickness of them as would at first appear. Matters are also rendered difficult by a reappearance of the massive limestone near Limeri on the Pindar river. But as the stratigraphical details of much in this neighbourhood are at the present moment not worked out, further remarks on this head would be premature.

North of Sirobagar.—Several of the specimens next to be described agree in a way that can scarcely be accidental with those described by Col. McMahon from the Darang ridge,[3] and also with some from the lower Chakrata volcanic beds in Jaunsar, *viz.*, Nos. $\frac{8}{406}$, $\frac{8}{407}$, and $\frac{8}{408}$ from the Gam Gadh, collected by Mr. Oldham. The likeness is not altogether a superficial one, as will be seen from the sequel, so that, though I am generally averse to generalizing on petrological grounds, I cannot refrain from drawing the reader's attention to the probable contemporaneity of these three sets of lavas. It should be borne in mind, parenthetically, that the lower

[1] See Rec. XX, p. 162. [2] See Rec. XX, p. 34. [3] See Vol. XV, p. 155.

Chakratas are the oldest beds in Jaunsar, and that beds underlying the volcanic series in the district I am describing have at their base some splintery slates, grey and purple in colour and without a trace of schistosity, abutting against the Dudatoli schistose series. The regional metamorphism of the Dudatoli schists must therefore be attributed to a cause which acted before the younger slates, limestones and superposed lavas were laid down. Thus those schists belong to a very ancient land area; and even the subsequent intrusion or development of the gneissose-granite in them must date back to a geologically remote period, since the attendant garnets in the schists as previously shewn (Section II) were also anterior to the deposition of the upper portions of the younger series near Lobah, and contemporary with that of the ancient rhyolites.

The following specimens are from the cuttings in the road which runs from Srinagar to Rudarpraeg along the river. Taken together they form an important series illustrative of a structure constantly present in nearly every crystalline igneous rock that I have yet seen in this section of the Himalaya. I refer to the apparent foliation of the rock at its upper and lower surfaces. At one end of the series we have a massive compact rock, breaking independently in any direction after the manner of an ordinary trap. It is purple, or greenish purple in colour, and crowded in many parts with amygdules of red and white chalcedony, of dark green chlorite, of calcite, and occasionally of more than one of these substances together in the same amygdule. At the other end of the series we have a rock undistinguishable from a chloritic schist, of a pale greenish grey colour, slightly soapy to the touch and very fissile. It is almost as fissile as a slate, the dip of the laminæ being parallel with the dip of the beds. But the chief point of interest in the rock seen macroscopically is that there are several dark-green flakes covering the cleaved surfaces, and some few of chalcedony, which are nothing less than drawn out and pressure-flattened amygdules. Between the two extreme forms there are a number of intermediate ones shewing more plainly, and step by step, the transitions from the perfectly formed amygdules to the mere blotched remnants of them, flattened, drawn out lengthwise, and sometimes separated into shreds. Along with this change in the amygdules the rock itself becomes more fissile, and develops gradually a greener colour through the dissemination of the chloritic amygdaloidal contents (see diagrams I, 1, 2, and 3).

Taking into consideration the perfection of the transitional varieties in this series of specimens, it seems impossible to explain them except on the supposition of pressure and cleavage acting after the rock had assumed its solid form. For, it is to be noticed, the amygdules are composed of just those minerals into which a trap rock naturally changes through the alteration of its primitive mineral components, and the formation of secondary products. Chlorite, calcite and chalcedony are always due to secondary causes when present in igneous rocks—secondary causes which are not likely to have come about rapidly, and whilst the rock was still warm from its eruptive phase, but which are universally regarded as working slowly, *e.g.*, steady pressure in the presence of water or steam, but continued over a long period of time. Thus we seem bound to admit a primarily molten condition of the rock, full of vesicles which cooled and hardened; after this a gradual absorption of some of the mineral constituents and the re-depositing them in vesicles as chlorite, chalcedony, &c.; and

after this a pressure acting on the cold and solid rock which re-arranged the particles of the rock at right angles to itself, *in toto* producing cleavage and a spurious schistosity.

It should be noted here that the more fissile varieties are always next the outer surface of the bed, or set of beds, whilst the massive non-fissile rock is always near the centre, just as in the case of the gneissose-granite bands. The pressure foliation which I here advocate as the explanation in these basic rocks, I have, in a preceding paper, indicated as the possible explanation of much of the foliated and semi-foliated forms of the gneissose-granite; and further on I shall shew that a microscopical investigation of the Hansuri band bears out this view.

Specimen No. $\frac{7}{76}$, locality a little north of Sirobagar. Sp. gr., 2·75. Contains 56·91 per cent. of silica. This was the most massive, and the least altered by subsequent pressure.

Microscopical.—A very large portion of the ground-mass appears dark and unchanged under crossed nicols, indicating the presence of a glassy base or one very slightly altered indeed. The whole of the slice appears even darker in tint than the glass of the slide owing to the presence of a large amount of opacite in irregular minute grains. Thickly disseminated in the base is a sprinkling of microlites of plagioclase felspar, all radiating in different directions. They generally shew twinning, the twins extinguishing under crossed nicols very nearly parallel with the nicols and almost simultaneously; a very few larger micro-crystals of plagioclase dotted about the field shew it more markedly. This is characteristic of oligoclase. A faintly fibrous green mineral, probably chlorite, is irregularly intermingled with them, and has no effect on polarized light. It is also collected together in many of the amygdules, which are usually round or oval in section. In some pear-shaped amygdules containing this green mineral there is evidence of a slight general effect of greater darkening in certain directions when the nicols are crossed and the stage revolved, but generally they remain completely dark. There is no trace of micro-quartz in the slide, the only form of silica being the chalcedony of the amygdules. This appears rather to have been injected from a foreign source into the rock than to have been derived from the surrounding portions of it. There are no minerals belonging to the amphibole or pyroxene groups. The amygdules of chlorite may, it is true, represent material derived by alteration of one of these minerals; but from the large amount of viridite in the ground-mass, they may be merely segregations of that material which in itself never had the opportunity of crystallizing out in the form of hornblende or augite; in other words, as Col. McMahon suggests for the Darang lavas, the glassy base may have been partly altered into viridite. The most marked appearance in this rock-slide is undoubtedly the chalcedony. The amygdules of it are frequently encased in a thin layer of chlorite and calcite. A concentric zonal arrangement of the silica marks the growth lines within the original vesicle. Irregular cracks traverse the substance. On crossing the nicols the mass of the amygdule splits up into sub-angular portions, each of which shews a radiating or sometimes parallel streakiness of grey-blue and pale yellow colours, which darken in directions parallel with the crossed nicols when the stage is revolved, thus partially displaying a black cross. The zonal arrangement seen by ordinary light is always at right angles to the radiating structure seen in polarized light.

No. $\frac{7}{74}$. A dark greenish-grey compact rock, slightly fissile, the amygdules a

little flattened and drawn out. This specimen very much resembles $\frac{7}{775}$ being taken in fact from almost the same locality. The ground-mass is very slightly coarser and richer in microlites of oligoclase. The latter are longer and very slender, almost like hairs, and often collected in stellate or cruciform groups. The large amygdules shew no differences worthy of note except with regard to their included crystallites. These are larger and appear to be mulberry groupings arranged in rod-like forms as well as circular. The chlorite amygdules are very marked, each with a border of chalcedony. Another set of irregular lacunæ are filled by an intimate granular mixture of viridite and chalcedony. There is then no radiating but only a very fine granular structure under crossed nicols, the viridite having hindered the proper action of the spherulite-forming forces.

No. $\frac{7}{778}$. A greenish grey very fissile rock, the amygdules being completely drawn out into blotches. It is taken from near the same locality as the two previous specimens, but not far from the surface of the flow. It resembles them very much in its intimate structure, but the re-arrangement of the particles of the rock in parallel directions is as marked under the microscope as is the fissile character in the hand. The microlites of triclinic felspar are a little more ragged and kaolinised, and are not so sharp as in the preceding examples; still there is no clastic appearance whatever, no suggestion that it is an ash. The lacunæ full of chlorite appear teased out at their ends and amalgamated more or less with the ground-mass as also do the clusters of opacite. The slice has a general striped appearance in consequence. The teasing out of the opacite clusters is very characteristic, and perfectly resembles the spluttering caused by a bad pen.

No. $\frac{7}{779}$. A slightly coarser grained rock than the above, of greenish-grey colour, from the same locality. The amygdules to the eye have almost lost their individuality. The parallelism of some of the larger needles of triclinic felspar and of the opacite, and the thin drawn out shred-like edges of the green mineral where it fills lacunæ, all shew the foliated or cleaved condition of the rock perfectly well. Much of the green mineral in the ground-mass appears restricted in a more marked way than in any of the other specimens, as though, owing to the coarser nature of the rock, it represented the altered result of some previously half-crystallized mineral. Under the $\frac{1}{4}$ inch objective there can be seen numerous small fragments and aggregates of a greenish-yellow mineral. It is impossible to say whether these belong to epidote, which seems most likely, or to some form of amphibole or pyroxene.

Gwar and Biraon, along the ridge N. from Charmarguri trigonometrical station. —The first three specimens to be mentioned have a very general resemblance to those from N. of Sirobagar, but the remainder shew a gradual change into a completely holo-crystalline rock. The localities are within a few miles of one another.

No. $\frac{7}{780}$ *Biraon.*—It very much resembles No. $\frac{7}{776}$ from near Sirobagar. A good many of the lacunæ filled with chlorite are teased out in appearance and the arrangement of the microlites of felspar is somewhat parallel.

No. $\frac{7}{781}$ *Biraon.*—Under the microscope this rock presents a wavy, drawn-out aspect (not unlike flow-structure) of alternating layers of viridite and finely granular quartz, containing great numbers of twisted and broken microlites of oligoclase. The pale bright green layers of viridite under the $\frac{1}{4}$ inch objective have the usual fibrous, faintly linear arrangement, which so strangely mimics flow-structure in a glassy rock

that it is difficult to explain them entirely on the supposition that they are only drawn-out amygdules, and not part of the original glassy base altered into viridite. Probably the truth lies between the two. The granular quartz layers, however, are undoubtedly merely a further stage of a crushing out of the chalcedony amygdules, or rather of the less pure ones mentioned in No. $\frac{7}{776}$. Magnetite is present in large quantities, as clusters drawn out with the rest of the rock structure, and twisted into most fantastic shapes. Under the high powers it appears to be aggregations of very small four-sided figures. There is another mineral which cannot well be distinguished from the magnetite under the 1-inch objective, but which, under the $\frac{1}{4}$ and $\frac{1}{8}$ inch, comes out distinct from it. It is present in the form of irregularly circular or hexagonal figures, of dull olive-green colour and with no action on polarized light. With them are associated some very minute red garnets, so that it seems probable that the former are the melanite variety of garnet. Epidote in brightly polarizing grains and in short prisms is also present in very small quantities.

No. $\frac{7}{785}$ *Gwar.*—This specimen and the next to be described both shew a smaller amount of the original glassy base and a relatively more developed stage of the microlites of felspar. The present specimen is an aggregate of small micro-crystals of oligoclase in lath-shaped sections very well and strongly developed, but shewing a considerable amount of granular kaolinisation under polarized light, with feeble colours. They are set in a very small amount of base in which the opacite is scarcely separable. Lacunæ of chlorite, though of irregular contours, are very distinct from the base itself in which there is but little of the green mineral. There is no free quartz, nor are there any amygdules of chalcedony.

No. $\frac{7}{784}$. *Gwar.*—This rock is a fortunate link between the more eruptive character of the foregoing specimens and the more thoroughly crystalline forms to be described next. It is not composed entirely, either of large crystalline elements, or of microlites; but it is a porphyritic rock. The porphyritic crystals are large, frequently rectangular felspars, much altered into quartz of corrosion, but there are not many in the slide. There are also a few crystals intermediate between these and microlites, which often shew twinning, the angle of the hemitrope section giving between the two extinctions a value of about 38° in some cases, and lesser values in others. The porphyritic crystals, owing to their corrosion, are quite unrecognizable; the developed quartz granules not even polarizing concordantly. The microlites in the glassy base, which form the ground-mass, all shew extinction angles of the smallest possible amount, *viz.*, about 3°. Many are twinned, the twins extinguishing almost simultaneously. It seems probable therefore that the whole of these felspars are really triclinic and oligoclase. The rest of the ground-mass closely resembles that of Nos. $\frac{7}{775}$ to $\frac{7}{776}$.

No. $\frac{7}{786}$ *N. of Gwar.*—A finely holo-crystalline greenish rock. Sp. gr. 2·70. In the hand, and when a thin slice is held up to the light, it appears to be a mixture of felspar and some greenish mineral; but when it is applied to the microscope the felspar is discovered to contain quartz-pegmatoid and also quartz of corrosion (Fouqué and Levy); that is to say, the felspar has intergrown with the quartz to form the pegmatoid structure, and has been changed by infiltration of silica to form the corrosion structure. Very little of the original felspar is left in the latter case, but sufficient to be recognized.

In diagram I, 4 I have sketched an example of corrosion of the felspar, which very much resembles that figured by Fouqué and Levy,[1] but in the slide under description there seems to be an intermingling of this structure with the pegmatoid structure. The cuniform outlines of the quartzes in the felspar shape, which are sometimes Z-like, sometimes hexagonal or irregular, are fitted together at their angles and occasionally run into a vermicular radiating structure towards some point in the changed felspar. They always extinguish light under crossed nicols simultaneously in the same crystal of corroded felspar, that is to say, each of the semi-detached portions of the quartz have a connected crystalline structure as if they were figures stamped out of a single quartz. According to Fouqué and Levy the development of the quartz of corrosion must have taken place after the solidification of the felspar, and there seems no doubt that this has been the case here, for the original outline of the felspar is quite sharp and distinct as indicated by the edges of the corrosion quartz. Nevertheless triangular quartz sections joined to each other, apex to base (not seen in the diagram) in lines parallel or radiating towards a centre,— all of which structure is characteristic of quartz-pegmatoid—indicate simultaneous crystallization of felspar and of quartz. Since then these two structures are found together in the same rock melting into each other, though one may be a primary and the other a secondary structure, they must be nearly related. Possibly the latter followed very hard on the crystallization of the felspar; or the originally felspathic rock was sufficiently re-heated and charged with silica as to allow the molecules to re-arrange themselves into the pattern of quartz-pegmatoid.

A previously twinned structure in the felspar is indicated by the quartz of corrosion pattern polarizing in different shades on each side of the median line. The singly twinned felspars and the non-twinned felspars may be orthoclase, but it is difficult to say with certainty.

The remainder of the rock consists mainly of long, singly twinned prisms of dark greenish-grey colour under the 1-inch objective, but which under the higher powers shew as crystal outlines with minute grains of chlorite dotted about them. The few spaces of the field between and among the above mentioned minerals are occupied by chlorite, whose minute portions and fibrils polarize independently, giving a speckled or irridescent effect. Opacite abounds, in irregular grains.

This altered rock may have been originally a diorite or syenite; but it is impossible to say with certainty whether the felspar was orthoclose or not, and whether the greenish-grey prisms were originally hornblende or augite. On the whole, analogy would prefer to call it a metamorphosed diorite.

No. $\frac{7}{780}$. *N. of Gwar.*—A reddish finely holo-crystalline rock. Seen in the hand alone it resembles a diorite or syenite; but under the microscope, as in the previous example, the felspar appears changed into quartz of corrosion. There is also apparently some original granular quartz, not merely replacing the altered felspar. Quartz-pegmatoid structure is rare. The green mineral is altered beyond recognition into chlorite, but from the long prisms and by analogy it seems likely to have been hornblende. They are often long, singly-twinned, dark grey, prisms, intact,

[1] Minéralogie micrographique. Planche XI, 2.

but having very little effect on polarized light. Opacite is present in grains and also in irregular blotches and pseudomorphs after replaced crystals of the unknown green mineral.

No. $\frac{7}{786}$. *Across the river opposite Limeri near Rudarpræg.*—A dark-green, coarsely granular rock with glistening crystals. Sp. gr. 3·06. It is perfectly holo-crystalline, containing large lath-shaped prisms of felspar which remain uniform under polarized light, or darken so slightly, owing to their alteration, as to be undeterminable, by the extinction angles. There is a yellowish or greenish mineral polarizing in bright colours. Most of it, of a pale and cold tint is not dichroic and is much cut up by cleavage planes, which blacken and become wider in certain portions of the crystals. A broken octagonal section shewed three very distinct cleavages (see diagram I, 5), the most developed being parallel with the clino-pinacoid, and two others, nearly at right angles to each other, being parallel with the faces of the rhombic prism. The mineral is therefore diallage. Other sections of it shew it to be diallage or augite according as the clino-pinacoidal cleavage is strongly or weakly marked. The outer portions of some sections of this mineral shew a change from the cold yellow, which is not dichroic, into a warmer more greenish-yellow, which is highly dichroic. They also shew in parts the cleavage of hornblende. A hexagonal basal section, (see diagram I, 6), adjoining one of these hornblende borders shews the characteristic rhombic cleavage of that mineral, the angle measuring 123.° This section is strongly dichroic and extinction takes place under crossed nicols dividing the angle of 123.° The rock contains therefore both hornblende, and diallage or augite; and the first seems to be produced by alteration of the others. A further stage of alteration is reached by the production of chlorite, which in many cases replaces the whole of the green mineral and is invaded by blotched parallel lines of magnetite, which has been aggregated by infiltration along cleavage cracks. The chlorite is in fairly large, fan-shaped tassels, which polarize light in pale but brilliant colours. The felspars are the most perfect in shape and crystallized first. Then came the green mineral, which only very occasionally has a half-perfect crystalline form. Finally, there is a small amount of quartz, filling in the inter-spaces. It is never present in rounded grains or regular hexagons, but always in groupings suggestive of a secondary origin by corrosion. The irregularly shaped grains are roughly fitted together, but with thick dark bordering lines, and not in polysynthetic aggregation. They polarize simultaneously in groups, and in many respects resemble the corrosion quartz in Nos. $\frac{7}{786}$ and $\frac{7}{785}$, but they never so manifestly take the place of the felspars as in those rocks.

There are other small groups of a clear colourless mineral with a tesselated appearance which remain dark under crossed nicols. They must be tridymite. (See diagram I, 7.) Along with much of the chlorite and the secondary corrosion quartz just mentioned they fill up lacunæ among the other crystalline elements of the rock and are probably due to secondary causes entirely.

This is an interesting specimen in connection with those previously described, for it is the first having a holo-crystalline structure, which definitely shews what the original green mineral was which is represented in the more eruptive rocks by chlorite or some unrecognizable mineral. I will return to this subject after some few more rocks from a neighbouring locality have been described.

No. $\frac{7}{407}$ *Sonal near Dhanpur.*– A greenish-grey finely granular rock. It is holo-crystalline, composed of triclinic felspars in long blades, and augite in broken prisms and a few basal sections. The augite is of pale greenish-yellow colour. It is not dichroic, and the octagonal basal sections shew cleavage angles of about 84°. The prisms also shew angles of extinction at their sides in some cases nearer 30° than 20°. Thus there is no doubt that the mineral in this case is augite, and not hornblende. Only in a few places in the slide has the augite become altered at the edges into a much warmer, darker, dichroic mineral. This is no doubt a stage preceding the development of hornblende. There is no chlorite in the rock at all. The polarization colours of the augite are very brilliant. The triclinic felspars are much kaolinized and shew but little twinning and darkening under crossed nicols. Its species cannot therefore be determined. There are a few irregular granular quartzes in the rock, but there is no corrosion-quartz certainly present. Opacite is present in irregular grains and pseudomorphous after augite. The mineral composition of this rock taken in connection with that of the preceding one indicates that among the whole spread of these basic lavas there are numerous passages between gabbros, diabases, and diorites; and it follows that the hemi-crystalline representatives of these which only contain the green mineral chlorite cannot therefore be called definitely either basalts or andesites.

No. $\frac{7}{413}$. *S. of Dhanpur.*—A greenish grey fissile rock. Under the microscope it is composed of irregular layers of chlorite and granular quartz set in a still finer matrix of broken and crushed up material, cataclastic in nature perhaps rather than pyroclastic.[1] It seems to be a further stage of the crushing up of a flow, in which the triclinic felspar has become kaolinized, and corroded, and rolled out, as it were, under pressure into granular quartz interbanded with chlorite. Opacite is in irregular grains and in long dusty clouds. The rock is therefore a chloritic schist which represents the ultimate stage of alteration of the basic lava.

No. $\frac{7}{415}$. *Near Bhatkúwáli.*—An inky-purple coloured, finely cleaved rock. This is so often found associated near the edges of the undoubted lava flows that, though it has all the appearance in the hand of being a slaty rock, it must, I think, be put down as a crushed igneous rock, the same generally as the last described. Under the microscope it is seen to be composed of a very fine clear granular matrix, very densely crowded with opacite in hazy clusters drawn out with the cleavage of the rock. When the nicols are crossed the ground-mass shews a very fine crypto-crystalline assemblage of little needles of felspar and other granular material of the finest description. There is no augite or other green mineral. I cannot say definitely that it is not an ash, but I should incline rather to consider it as cataclastic than pyroclastic.

We may now sum up generally the whole of the evidence afforded by this basic volcanic series, and see what results it leads to, and in what respects the rocks agree with the Darang series.

(1) The flows are massive towards the centre, and foliated or cleaved at the upper and under surfaces. From the evidence of the amygdules these structures seem to be due to pressure acting on the rock through long ages after it had cooled, and not to be due (at least mainly) to differential motion of the particles by fluxion.

[1] Using the terms lately proposed by Mr. Teall, Geol. Mag. Decade III, Vol. IV., p. 493.

(2) The felspars in the eruptive phases of the rock are always oligoclase, clear, pellucid and twinned; and they grade upwards in size from very minute ragged needles to large microlites and micro-crystals, as the more holo-crystalline varieties are reached.

(3) The intimate structure of the foliated rock seen under the higher powers of the microscope shews as clearly as in the hand specimen its drawn out or cleaved condition by the parallelism of the felspar microlites, and the smudging out of the opacite, chlorite, and chalcedony. A final disintegrated condition of the felspar gives with the chlorite a simple chloritic schist.

(4) As the rock becomes perfectly holo-crystalline, the felspars appear (*a*) kaolinized, so as to preclude recognition by the polariscope; (*b*) changed into quartz of corrosion, with the same result; (*c*) in the pattern of quartz-pegmatoid.

(5) The green mineral in the more eruptive phases of the rock is always viridite with no action on polarized light; or some form of chlorite in fine fibrils or fan-shaped clusters, with positive action on polarized light; or occasionally epidote in minute quantities. No augite or hornblende have been detected in the rocks which possess a glassy or slightly altered glassy base. Probably much of the pale, clear viridite represents an altered condition of the base as suggested by Col. McMahon, but in many cases the restricted patches of it seem to point to a change *in situ*, from some pre-existent crystal of amphibole or pyroxene.

(6) In the holo-crystalline rocks we find the green minerals, augite, diallage and hornblende co-existing with felspars, kaolinized beyond recognition or changed to quartz of corrosion. We find opacite in pseudomorphs. Chlorite is rare along with augite, but the borders of the latter shew alteration into hornblende. Where both augite and hornblende are present chlorite begins to predominate. Diallage is present in some few specimens passing from or into augite. We seem to be driven to the conclusion, therefore, that the beginning of the green minerals in these rocks was as a chloritoid mineral and the final end of them the same. Those stages of the rock in which crystal-building was arrested by prompt cooling shew it in the ground-mass and also in lacunæ to the exclusion of other minerals; and the fully crystallized stages also shew it as the result of the breaking up of the other minerals.

(7) The Darang lavas described by Col. McMahon have therefore some points in common with these rocks as a whole, though not with any one in particular. In the first place they cannot be distinguished in the hand specimens, particularly Nos. 7 and 11 of his published series which shew slightly crushed amygdules. Next the large amount of viridite, or some form of chlorite is strikingly like the cases I have described. He has however found augite in the hemi-crystalline forms, whereas in this neighbourhood there is no unaltered green mineral present, save in those of holo-crystalline structure. With regard to the felspars, I think they are identical, at least in the more eruptive phases of the rock. Col. McMahon names the felspars of No. 1 of his Darang series labradorite, but in sections I had made of this rock and of No. 2 of the same set the microlites extinguished under crossed nicols at a very small angle with their sides, certainly not more than 3°, which is a characteristic of oligoclase. The almost simultaneous extinction of the twinned halves also bears the same interpretation.

(8) Owing to the evident change which has been induced in all these rocks by

permeation of acid waters, which has saturated them in places and left them intact in others, but little reliance can be placed on data derived from their specific gravities and percentages of silica.

(9) With regard to the stratigraphical classification of these volcanic strata, I can do little beyond throwing out a hint, that their wide extension, apparent great thickness, and general resemblance to the Darang and Bombay basalts, should make us look towards the corresponding great thickness of the lava-fields which form the Deccan in Peninsular India for their most likely equivalents. This would make them about cretaceous in age; and if the massive limestone which underlies them corresponds to the massive limestone which underlies the Tál beds in W. British Garwal, this conclusion is further warranted by the mesozoic age of the fossiliferous Tál beds.[1] There are some difficulties, however, in the way of this correlation—their possible equivalence with the Chakratas in Jaunsar being one—so that I do not think it worth while developing the idea any further at present.

PART II.

PINDWALNI ROCK.

I will now pass on to mention a rock which I am grouping next these basic lavas, although it is completely isolated from them, occurring in fact, among the Dudatoli schists, and although it is perfectly holo-crystalline and of a still more basic character than they. I have called it the Pindwalni rock, as it is exposed very near the village of that name distant 4¾ miles north 35° west from the north peak of Dudatoli (10,188 feet). I came across this rock loose in stream-beds many times before I could trace it to its home, notably as pebbles in the Chifalghat or west Nyar river near Paithana; in the Pindwalni stream; and in the small streamlet south of Bhalson opposite Bani Thal. *In situ* I eventually found it 2 miles south-east of Khand M., on the Chifalghat, and about ¾ mile south-west of Bhalson. It is there in the form of a thin dyke (30 feet?). Occurring in this region it is of interest as being very analogous to the so-called dolerite of the Chor, and I shall shew later on that its mineralogical composition is very probably almost identical with that rock, as described by Colonel McMahon.[2]

No. $\frac{7}{400}$ *near Pindwalni.*—A very dark greenish rock exceedingly tough and difficult to break with the hammer. Sp. gr. 3·01. Contains 40 per cent. of silica. The low percentage of silica in this rock and its high specific gravity prepared one to expect the presence of either anorthite or labradorite as the felspar representative. Under the microscope this is found to be the case, the rock-slice appearing as a holo-crystalline mixture of clear pellucid labradorite crystals, elaborately twinned and full of small crystallites; together with a pale yellow mineral, in small quantities; and a darker greenish mineral, generally decomposed beyond recognition into a chloritoid result. Titaniferous iron is also present. Taking the last mineral first for consideration, it is found largely represented either in irregular grains of opaque black material, or as skeleton trough-like forms, roughly hexagonal, with growth or decay lines crossing one another at angles of about 72° Among the six

[1] See Rec. G. S. I., Vol. XX, p. 34.
[2] See Rec. G. S. I., Vol. XX, p. 113.

sections, I had made of this rock, I found occasionally a bordering or striping of the mineral with a neutral tinted substance, which is probably the unknown leucoxene. Deep amber-coloured sphenes of small size are also fairly numerously dotted about in one section.

The other minerals in the rock are hornblende, very much altered; augite in small quantities; and mica, which last is only found in one section. The hornblende was for a long while undistinguishable, as several of the prepared slides shewed too much alteration of it into a chloritoid mineral. Eventually one of the sections gave a number of slightly dichroic brownish-green irregular forms, among which those with a prominent cleavage in one direction made extinction angles of 20° and under, with the cleavage; and one displayed a basal section with two sharply marked cleavages exactly at an angle of 124° with each other. Generally, however, the hornblende is so wholly altered as to have nothing but an aggregate effect on polarized light after the manner of radiating groups of chlorite. The augite is a very pale brownish yellow in colour shewing no dichroism. It possesses ragged outlines and is usually set in a mass of hornblende or altered hornblende. There were no sections characteristic of augite, but its scaly surface, numerous cleavage planes and brilliant polarization colours seem to indicate this mineral unmistakably. It seems extremely probable that the augite was the first and original green mineral in the rock, and that it was first altered into hornblende and that in turn altered into chlorite. Numerous sections bear out this view, for the cleavage lines in the pale nearly colourless augite run undisturbed into the dark brownish-green dichroic hornblende; although the minuter structure of the mineral, including its colour does not fade away from one to the other, but is very abruptly marked off (see diagram II, 8).

The most interesting mineral in the rock is the labradorite. It is coloured a pale warm drab of lighter and darker shades melting into each other. It occurs in very beautiful twins chiefly after the albite pattern, associated also with pericline twins. Carlsbad twins seem also to be combined with these in many cases, as indicated by the change in the direction of the indistinct basal cleavage on each side of the twinning line. Numerous examples of the albite twin when hemitrope in the zone at right-angles to the clino-pinacoid, shewed angles between the two extinctions on each side of the twinning line from 38° to 63°, the values 50°, 53°, and 55° predominating. In rectangular sections with two very distinct cleavages nearly at right-angles to each other there was once visible between the two hemitrope extinctions an angle of 62° which is the greatest possible for labradorite. There were none exceeding this so that the mineral cannot be anorthite. The polarization colours are blue-grey and pale yellowish-brown, and they have a very clear definition in nearly all cases. No kaolinisation whatever of the felspar has taken place, except as exhibited in one section, where curiously the hornblende is better preserved than usual.

A striking feature in the labradorite is the innumerable small clear crystallites which throng it. In most of the plagioclase sections they seem arranged as irregularly as a pack of cards thrown on the floor, but in some few they are gathered along definite lines either parallel with the sides or the cleavages of the labradorite. They are clear, pellucid and colourless, and possess a fine, but distinct outline. Their

shapes are slightly elongated prisms, rhombs, hexagons, and rectangles (see diagram II, 9). Some appear to have no action on polarized light, others have a feeble action, the colours being pale blue-grey and yellow, but quite independent of those of the labradorite in which they lie. In some cases they are scattered sparsely, and in others they are packed into dense masses so as to slightly obscure the natural appearance of the felspar. They shew no internal structure such as cracks or cleavage. They do not stand out with the characteristic relief, nor have they the jointed appearance of apatite: some few long, jointed prisms of apatite, actually present in the slide, rendering this contrast the more striking. They are entirely confined to the felspars and may probably be tridymite, developed along the cleavage planes, after a habit which tridymite is known to affect. The presence of undoubted tridymite in slice No. $\frac{7}{87}$ lends support to this idea, and favours the theory of its secondary origin.

There is no free quartz in the rock-slice as would be expected from its low percentage of silica: a percentage which also makes it difficult to understand even the presence of the tridymite, although doubtless the thinness of the shapes prevent their aggregating very much. In this connection its presence at all in such rocks as the Limeri rock (No. $\frac{7}{87}$) is remarkable, as it is generally wanting in all basic rocks.

I have not seen anything that I could with certainty call olivine in the rock. One or two small isolated pale minerals which I have classed with the augite may possibly be olivine, but I am inclined to think that it is altogether absent.

The specific gravity of the rock: the peculiar colour of the felspars which cannot be resolved under the higher powers of the microscope into any thing more than a faintly striped appearance: their regular shape: their belonging to the labrador species: the irregular ground-work of augite and hornblende in which they lie: the clearness of the twins, and the forms of the twins: the forms of the black mineral in large decomposed or replacing crystals, and the change of it partially into leucoxene, all seem to correspond in a marked way with the described structure of the dolerite of the Chor.[1] The main difficulty in the way is the apparent absence, in the specimens from the latter place, of the supposed tridymite in the labradorite. Still that mineral may be the effect of local schilleiization in this particular area.

This Pindwalni rock, as I have already mentioned, is typically perfectly massive without any parallelism among its parts. At its upper and lower surfaces however it becomes foliated in the same way as the gneissose granites and the basic lava flows do. It was unfortunately impossible to obtain a specimen of the foliated portion *in situ* for slicing sufficiently undecomposed, so that the next specimen to be described had to be collected in the stream-bed south-west of Bhalson. As this stream is very small and the Pindwalni rock crops out in its upper part, I think there can be no reasonable doubt that it is really derived from the same bed as the Pindwalni rock, but at one of its surfaces. In addition it may be mentioned that the ordinary Pindwalni rock was scattered about in the stream in the immediate neighbourhood.

No. $\frac{7}{98}$. *Stream south-west of Bhalson.*—A black and white foliated rock. Under the microscope it is seen to be very well foliated indeed, and to consist largely of layers of quartz and felspathic material interbanded with layers of a decomposed greenish

1 See Vol. XX, p 114.

mineral either hornblende or mica. Eyes of felspar are seen much drawn out, crushed and corroded, so that they have a granular appearance especially towards the drawn out ends of the eyes. Under the ¼ inch objective by ordinary light this corroded or crushed structure is invisible, but there is seen on the other hand very prominently a number of included clear crystallites of exactly the same shape and arrangement as in the felspar of the Pindwalni rock. The crushing and corrosion of the felspar has of course obliterated all signs of twinning.

A very marked feature in this rock is the black mineral which is in irregular grains surrounded by quite a thick border of leucoxene of dark neutral grey colour, shaded towards the borders, and with a faint aggregate polarisation.

PART III.

SCHISTS AND GNEISSOSE-GRANITE NEAR HANSURI.

I now pass on to describe a few typical specimens taken from the schistose series and gneissose granite on the south side of the Dudatoli area. In section I of these papers I gave a general idea of these rocks viewed macroscopically, and a more circumstantial account of their field relations. The following notes will therefore strictly concern their structure under the microscope.

No $\frac{7}{860}$. *Stream below Kainur.*—Garnetiferous mica-schist of the most thoroughly crystalline type. Under the 1 inch objective the mass of the rock is seen to be made up of clear quartzes polarizing in very clear and fairly vivid colours. They have the usual granular structure belonging to a thoroughly crystalline schist, that is to say, the grains with irregular outlines, only sometimes visible by ordinary light, shew, when the nicols are crossed, intricate, curved boundaries between differently coloured crystalline portions. The quartz layer as a whole is traversed by very many irregular cracks which cross from one to another of the differently polarizing grains. There is thus no residual sedimentary structure visible, no worn grains suggesting an original deposition by aqueous causes: or in other words the quartz must have been at the period of its metamorphism in such a state as to allow free play for the molecules to arrange themselves into crystalline portions, the formation of one portion being only interfered with by the formation of its neighbour, or by the other crystalline ingredients in the rock.

The mica of pale brown and brownish-yellow colours is seen distributed in plates and irregular grains generally parallel with the foliation. They shew no cleavage. White mica is also present running in long lines and possessing a very noticeable cleavage.

Sharply marked off from the other constituents of the rock are the garnets which are pale claret coloured with a very well marked raised outline. Their forms are irregular polygons, generally more or less rounded. They are perfectly intact without any breakings or tendency to be drawn out or cracked, as in the case of the St. Bernard rock. In this respect they differ entirely from the garnets present in the "gneiss-granulitique" of the snowy range at Kedarnath, which are of a ragged, shred-like aspect as though merely filling interstices among the other minerals. The garnets are of several sizes, though there is a general uniformity in this respect among the majority of them. A few very minute ones are just discernible under high powers (¼ and ⅛ inch objectives). Within each of the larger garnets, which is of course

dark under crossed nicols, there shew up a large number of irregular cavities and included portions of other minerals. Towards the centre of the garnet these are quite dense, whilst the outer border of the garnet is quite clear. The cavities are chiefly gas cavities of oval, lenticular, and irregularly amœbiform shapes, only rarely shewing polygonal outlines approximating to the shape of the garnets, and herein differing again from the rocks at Kedarnath in which the garnets shew this structure conspicuously. The gas cavities are distinguished by their black borders which shade away gradually. There are other irregular inclusions devoid of crystalline shape which shew feeble colours under polarized light, and must consequently be some included crystallite. Opacite in irregular strings and blotches is also included with them, and occurs nowhere else in the rock. Some few inclusions with a fine outline seem to be of an aqueous nature.

Besides quartz, mica, and garnets, there is another fine fibrous mineral, clear and of pale yellow or greenish colour, arranged in brush-like aggregates and polarizing vividly under crossed nicols. The brushes of this mineral run among the other constituents of the rock. The fibres are long and rod-like, often divided across by cracks, which split them up like the usual forms of apatite or of bacteria. It is probably sillimanite. Doubtless it and the garnets and much of the mica were the last result of the metamorphism induced by the gneissose-granite of Dudatoli.

No. $\frac{7}{808}$. *From near the same locality as No.* $\frac{7}{806}$.—Whilst the latter represents more definitely a foliated richly garnetiferous schist, the present specimen is from a more arenaceous band. Under the microscope it very much resembles No. $\frac{7}{806}$ the quartz and mica being in very much the same condition except that the white mica is scarcer. The large garnets are absent, but there are a number of very minute ones in different parts of the field.

There is one mineral of faintly olive-green colour and rather dichroic, changing from a brownish to a bluish green, which under crossed nicols appeared to extinguish light only twice in a complete revolution of the stage of the microscope, *viz.*, when the long axis of the mineral, which was rod-shaped, was parallel with the horizontal nicol of the analyser. They were very small, but there were several examples in the rock-slice.

There is also another unknown mineral ramifying about in cob-web fashion, without any distinct structure, among the quartz grains. It did not seem to be perfectly isotrope, although in ordinary light it much resembled an imperfectly built garnet. Its nature I could not determine.

No. $\frac{7}{816}$. *Pokree E. Nyar R.*—This mica-schist resembles the other two specimens of this series except that it is much less well pronounced as a schist and finer grained. It has a smaller amount of mica in minute irregular grains, without crystalline outlines or cleavage, and brownish-green in colour. There seem to be no white mica and no garnets present. The quartz grains do not polarize in rich bright colours as before, but in more neutral tints, blue-grey and faint orange predominating, purples and reds being rare. Under the $\frac{1}{4}$ inch objective rod-like belonites of pale green colour are fairly numerous, and some few doubtful minute bodies which may be proto-garnets, but they have no decisive action on polarized light.

No. $\frac{7}{813}$. *Hansuri band of gneissose-granite.*—In section I, I described this rock macroscopically classifying it with the lenticular-tabular variety of the gneissose-granite. In briefly commenting on the structure I then said:—" I by no means imply

that the lenticular-tabular is necessarily an embryonic condition of the augen. It seems as likely that the reverse is the case."[1] I think I can now shew by the aid of thin slices of this rock and of the quartzite near Rudarpraeg that this lenticular-tabular structure is due rather to the coalescing by crushing of originally separate crystals of felspar and grains of quartz than to an attempt at the formation of individual crystals and grains from the primarily structureless folia. It is of the greatest importance to establish the right order in this phase of rock-structure, so as to give a rational basis for an opinion concerning the date of the foliation which has happened to nearly every crystalline rock in the Himalaya; the more so because this structure has recently been differently interpreted, and assigned as largely contemporary with the intrusion of the gneissose-granite and due to fluxion rather than to subsequent pressure. The evidence which I shall give here, and that already given in the case of the amygdules of the Sirobagar lava-flows, leaves, however, no doubt in my mind that it is a super-induced phase, having no reference to flow-structure, and which may have happened at any time subsequent to the cooling and consolidation of the rocks in which it occurs.

The first section I had made of this rock shewed the peculiarities represented in diagram II, 10. I examined it first by the eye with reflected light alone, in a fairly thick slice, and then with the hand-lens, and was able to make out the following:—A and B represent two crystals of orthoclase in the shape of eyes which are united together by a connecting portion *xy*, forming altogether the prevailing lenticular-tabular structure. When the light was allowed to fall obliquely on the rather thick section, the twinning of the two felspar eyes was most manifest. The portion *a* was more illuminated than *b* and *a'* than *b'*. The bridge *xy* shewed no twinning nor extra brightening of the felspar: it had a rough and crushed look. Thus although superficially the felspathic layer seemed homogeneous along its whole course, this experiment shewed that there was a radical difference between the eyes of felspar A and B and the felspathic material *xy*, such a difference as would be implied by two original crystals A and B having been crushed into each other or over each other, the debris of the crushing going to form the bridge *xy*.

Seen under the microscope the evidence is amplified by the greater power of detecting the individual portions of the felspar which have become detached from the original crystals, and which lie embedded amongst granules of quartz. The crystals of felspar present a very much dappled and altered appearance, but they shew characteristic cleavage and polarize in their different tints as a whole and display twinning on the Carlsbad pattern. They are thus sharply marked off from the debris of quartz and felspar which fills in the bridge *xy*. It is thoroughly seen what a ragged, broken edge the felspar has, how it is torn into shreds and mechanically corroded, worse than a crystal of quartz or felspar in a rhyolite. Any one examining this rock and observing how the complicated and beautiful structure of the felspar has been battered and buffeted, would be as incapable of believing that a granitic rock was being evolved under these conditions, and that felspar was being aggregated into orderly crystals out of this chaos of remnants, as he would be on seeing the fragments of a beautiful vase of imagining that they were the constituent elements out of which such ornaments were ordinarily made.

Diagram III, 11 represents a portion of this rock as faithfully as I can reproduce

[1] Vol. XX, p. 139.

with the means at my disposal. It is seen to be built up of layers of quartz and mica besides the lenticular-tabular felspar folia. The former constituents do not differ much in their arrangement from those in the mica-schist described from below Kainur. There are no garnets and but little opacite in the rock.

Thus, taking into consideration the fact that through the whole of the structural varieties of the gneissose-granite we have passage forms connecting the tabular-foliated with the perfectly granitic form; and that between two of this series, namely, the lenticular-tabular and the augen, the order of development has been demonstrated to be from the augen to the lenticular-tabular, we may provisionally accept as true, until the opposite is proved, the general statement that the foliation of the gneissose-granite is a structure induced on a normal granitic rock by movements of the particles of the rock over one another causing them to be crushed and their crystalline contents to be disfigured and distorted.

But it may be argued that this crushing and distortion may have taken place under half-molten conditions of the rock: it may be said that the evidence I have offered shewing differential motion of the particles of the rock would apply quite as plausibly in explaining flow-structure in a rock which contained partly solidified crystals: it is perfectly true that I have given sufficient reason for thinking the tabular-foliation to have arisen from an originally granitic state, but I have not shewn that this did not come about as Col. McMahon thinks[1] by immediate transformation of the imperfectly consolidated granitic paste into a foliated substance, by a movement akin to flow-structure having been set up in it in consequence of its having been forced into fissures among the bedded schists. In other words it is still necessary for me to shew that this crushed and foliated structure was induced on the rock *in the cold*, as a later production, perhaps a geological age subsequent to the original development of the granite. With this end in view I will describe microscopically a lenticular-tabular quartz-schist previously quoted by me in Vol. XX, p. 139.

No. $\frac{7}{705}$. *N. of Rudarpraeg.*—This quartz-schist in the hand specimen can be seen to be composed of grains of quartz without any felspar or anything that would suggest an igneous origin. Moreover in some places there are pebbles, perfectly rounded by water-action as large as a hen's egg. No one would be inclined to doubt that this rock was a metamorphosed sedimentary rock. Under the microscope it is seen to be composed of lenticular-tabular layers of quartz and finely powdered quartzose and argillaceous material, with very thin streaks of micaceous material bordering the lenticular-tabular layers. These layers are seen to be composed essentially on the same plan as those in the gneissose-granite of Hansuri, that is to say, eyes of quartz form the expanded portion of the layer and fragments of the same mixed with argillaceous material bridge over the interval between the two (see diagram III, 12). The quartz under the microscope seen by polarized light is of uniform colour or of two or more colours watered into each other over the greater part of its section. But towards its borders it becomes surrounded by several rainbow halos, which become less bright as they merge into the finer material of the rock. A striation following the foliation of the rock runs the pointed ends of the eyes into the finer material gradually merging them into one another. We have the following stages manifestly indicated by the present rock-slice: (1) an original

[1] See Geol. Mag May 1887, p. 212, and Rec. G. S. I., XX, p. 205.

approximately spherical condition of the grains of quartz; (2) a crushing and breaking up of portions of them, which are left *in situ* just as they were torn away from their parent grain; (3) a further pounding up of some of the fragments and a merging of them into the finer material of the rock; (4) a coalescing of this broken and powdered material with each end of a rounded grain of quartz to make an eye, and the concomitant development of the films of mica separating the lenticular-tabular layers.

I think no one will doubt that in the case of this rock the development of a lenticular-tabular foliation, exactly similar to that in the gneissose-granite band, has taken place *in the cold.* The only other alternative would be to accept a quartzite containing well-marked rounded grains and still larger pebbles, as a kind of igneous rock. As that alternative is impossible we must take it as proved that both structures have been produced in the cold and solid way.

In the earlier part of this paper I shewed that the foliation of the basic lavas near Sirobagar had, from the evidence of the drawn-out amygdules, been similarly accomplished since the rock had cooled and solidified. We have therefore instances in this part of the Himalaya of plutonic, volcanic, and sedimentary rocks, all having suffered this peculiar form of foliation. In other words, each of the great representative rock groups have been influenced by it impartially. We must therefore look for a far-reaching cause for this structure, and as we have seen that that cause must have been pressure resulting in crushing, we must invoke a universal pressure as the all-powerful agent: and the only universal pressure that we know of is that involved in the earth-movements which have been at work for ages building the Himalaya ever higher and higher.

REFERENCES TO PLATES.

Diagram I, 1, 2, 3. Illustrating the drawing out into shreds of the amygdules by pressure after consolidation in the Sirobagar basic lavas.

Diagram I, 4. Quartz of corrosion structure in altered diorite or syenite, from near Gwar.

" " 5. Diallage in gabbro, shewing characteristic cleavages in basal section from near Limeri.

" " 6. Basal section of hornblende in same rock, shewing characteristic cleavage at 124°.

" " 7. Tridymite in the same rock, filling a cavity along with radiating chlorite.

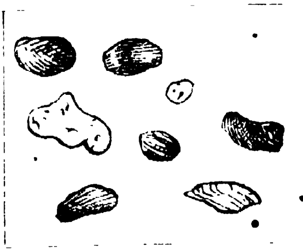
" II, 8. *a*=augite changing into *b* a dichroic hornblende-like mineral. *N.B.* the shading in b is not intended for cleavage lines.

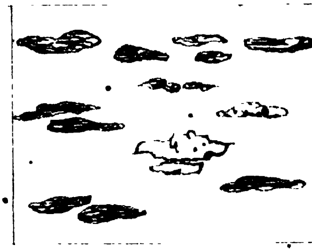
" " 9. Tridymite (?) crystallites developed in Labradorite of the Pindwalni rock. *d*=a massing of the crystallites along a cleavage crack.

" " 10. Lenticular-tabular structure as seen by the eye alone in a thin slice, Hansuri band of gneissose-granite: for reference see letter-press.

" III, 11. The same rock under microscope with crossed nicols. References the same as in 10. *e*=mica layers; *d*=quartz layer.

" " 12. Lenticular-tabular structure in quartz-schist near Rudarpraeg; with crossed nicols.





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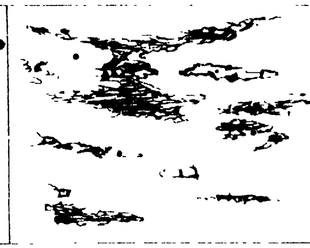

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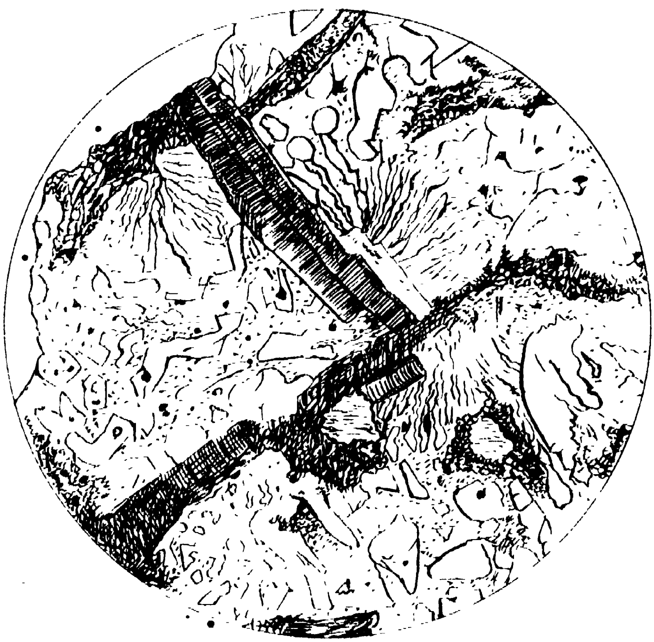

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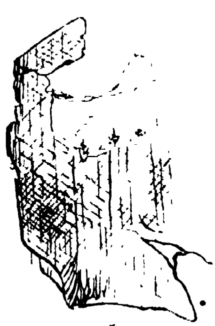

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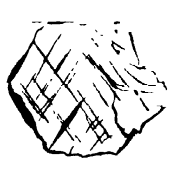

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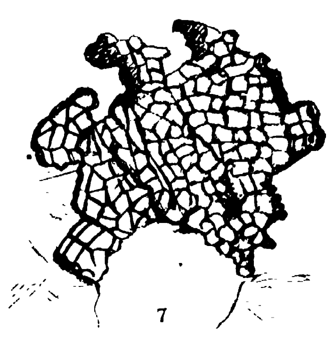

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DIAGRAMS I

Middlemiss

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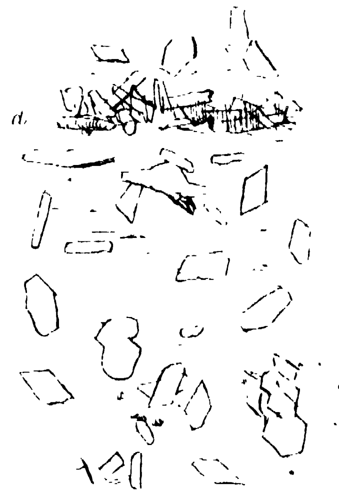

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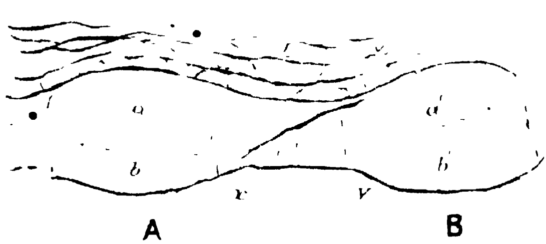

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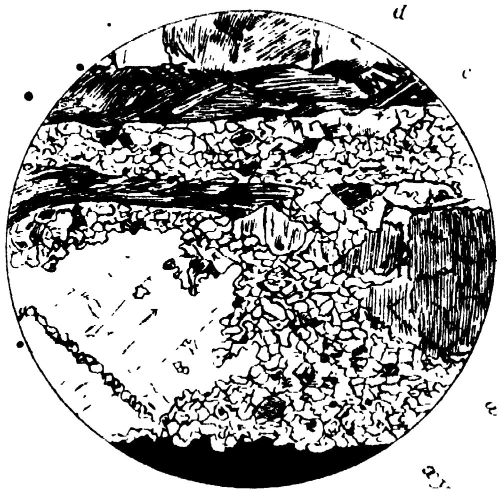
DIAGRAMS II



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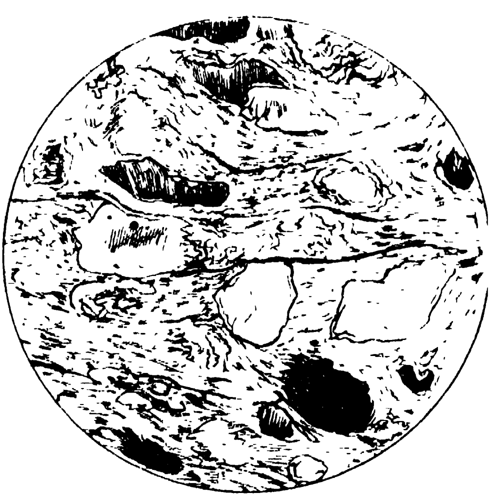


12

DIAGRAMS. III

The Birds-Nest *or* Elephant Islands, Mergui Archipelago. *By* Commander ALFRED CARPENTER, R.N., H.M.I.M.S., *S.S.* "*Investigator.*"

This remarkable group, called by the Burmans Ye-ei-gnet-thaik (lit. sea birds' nests) is located on the south-east side of Domel Island one of the largest of that chain forming the Mergui Archipelago at the southern extreme of British Burma. It is a small group of 6 marble rocks, the highest and largest of which, 1,000 feet, in altitude, and about one mile in length, is oval-shaped and rises very abruptly out of a depth of only 5 fathoms.

They present a very striking appearance, particularly if the weather is hazy, when they are not seen until within five or six miles; for then they gradually loom out through the mist like some huge mishapen monsters that have strayed away from civilization.

Their sides are partly clothed with vegetation wherever a break in the limestone has left a cleft in which moisture and dust can lodge. Conspicuous because of its leaning attitudes is a species of tree fern which appears content to grow at any angle, but only above a height of 200 feet from the water.

The face of the rocks is reddish, partly from weather and partly from soil; and where cliffs exist the most beautiful though uncouth stalactitic formation is at work, shewing grotesque and snake-like patterns varying in hue and shape, till one feels as in some ogre-enchanted land. But the great feature of the group are the birds nest caverns which, as a rule, open into the sea, the entrance being below high water mark; fortunately I visited them at spring tides and had plenty of leisure to examine each cavern in two days' low waters.

At the south end of the largest island stands a ninepin of grey marble, 370 feet high, almost separated from the rest. It is hollow like a huge extinguisher, and the polished light blue and light yellow sides of the interior seem to point to its having been hollowed by the swell of the sea, which on entering the cave would probably expend its force vertically, the mouth of the cave being open to the direction of the strongest seas.

This ninepin forms the western point of a nearly circular cove 360 yards in ~~diameter~~ which runs back into the big island, and the sides of the cove rise steeply though not perpendicularly from it. At the head of the cove is a perpendicular wall of rock over which can just be seen the 1,000 foot summit in the distance.

At half tide a tunnel opens under the wall of rock at the head of the cove, and a canoe can go through; but it requires to be within an hour of low water springs for a ship's gig to go through. This tunnel has a roof-covering with large stalactitic knobs, except at its narrowest part where it is apparently scoured smooth by the action of the tidal rush. It is about 250 feet long and 4 feet deep at low water, the rise and fall being 16 feet, and is covered with dripping marine life, corallines, small corals, comatulæ, sponges, and sea-horses. Passing through this submarine drain one emerges into another circular basin with perpendicular sides, which gives the impression of volcanic action, so like it is to a crater. This basin is only open to the sky; caves here and there open into it, some of which may perhaps lead by long tunnels to other basins. Water was running freely into it from the foot of the cliffs

in several places as the tide fell, shewing that water-spaces existed, and strange gurgling sounds, as of air taking the place of water, could be heard now and again. The first thought that strikes a European is "what a famous place for smugglers." There were hardly any signs of the place being utilized, except here and there the worn ropes of birds' nest climbers. It was either not the season for the swallows or they had deserted the islands, for none were seen. There was a little reddish guano in some of the caves. There was evidently but little traffic through the tunnel by which we entered, for the delicate growth on its sides was hardly injured.

On the west side of the northern large island a lofty cavern opens at half tide into another nearly circular basin of about the same size as that we have just described, but in this case the basin also opens into the sea on the east side of the Island. After contemplating the cliffs that surround these basins, and the general circular contour of the high ridges of these islands, and the undermining action of the sea at the water line, causing in some places an overhanging of 20 to 25 feet, and the softening of the marble surface of the cavern roofs by moisture; the impression gradually forces itself on one that these circular basins were themselves at one time the floors of huge caverns, and that in days gone by the islands were far higher, with cavern piled on cavern, and that the work of disintegration by moisture is slowly going on, pulling down these marble monuments of a giant age.

Indeed, here and there a fall of blocks has occurred lately, and from there being no shoal off the base of the slip the dissolving action, if such really occurs, must be rapid.

A small oyster covers the rocks at the water line. A handsome kingfisher was secured and sent to the British Museum. A few doves and an eagle or two were the only other birds seen, besides a small bat in the caves. By the position of the nest seekers' ropes, the swallows appear to build only on the roofs of the caves. The Islands appeared to be entirely composed of a blue tinted marble.[1] A vessel could be alongside them and lower the cut blocks straight into her hold, but it is probably of too poor a quality to be worth shipment.

Memorandum on the results of an Exploration *of* Jessalmer *with a view to the discovery of* Coal, *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.*

1. On taking up work I marched in the first place to Báp and commenced an examination of the country in that neighbourhood and to the north. I found that the boulder beds cropped out to the west of Báp, extending further in that direction than I had thought probable, and that they are there associated with a great

[1] Two specimens of the limestone have been sent to the Museum by Commander Carpenter; they are a very pure pale grey-coloured massive sub-crystalline carbonate of lime: in fact a marble, which if obtainable in fair-sized pieces would do for use or ornament where the colour is not objectionable, as for flags, wash-hand stand and table top.

development of dark red clays and shaly sandstones for the most part impregnated with salt.

2. To the northwards I traced the boulder beds as far as the limit of Jessalmer territory, beyond which they do not appear to crop out at the surface; and to the southwards I believe I have traced their utmost extent.

3. As remarked in my former memorandum,[1] this country is very unfavourable for geological observations, but I had no conception of how impossible it is to make a satisfactory detailed geological map until I had made the attempt. In the immediate vicinity of Báp and the Sird villages there are stream beds which do to a certain extent exhibit the rocks, but for the rest there is nothing but a vast undulating plain of sandy soil in which the underlying rock is represented by patches, varying in size, of pebbles, fragments of ferruginous sandstone or of concretionary limestone. Under these circumstances it is impossible to satisfactorily determine the true relations of the rocks, but one or two points stand out with some clearness.

4. First among these is the fact that wherever the rock immediately overlying the boulder beds is seen it is a hard, black ferruginous sandstone, with or without pebbles; it might be supposed that this indicated a conformity between the boulder beds and the ferruginous sandstone, but it may be, and probably is, merely due to the fact that, except where hardened by impregnation with iron, the sandstones do not shew themselves distinctly at the surface. Under these circumstances there is no proof that the different exposures of the black sandstone represent the same horizon, and it is by no means impossible that the boulder beds are unconformably overlaid by sandstones of upper gondwana age.

5. In the neigbourhood of the village of Akhádana there are some indications that such is the case. Here there are some low, rounded ridges, covered with shingle, in the hollows between which the boulder-bed is exposed. The matrix of the conglomerate from which the pebbles are derived is not as a rule to be seen, but, where this is a sandstone of the black ferruginous type, it occasionally crops up through the surface wash of shingle and the transition from the boulder beds with numerous large unrounded fragments of red syenite and malani porphyry to the conglomerates, in which these rocks are barely represented and then only by small rounded pebbles, is so abrupt as to suggest an unconformity.

6. If this be so, there will be but little use searching for coal in this neighbourhood, and there is another fact which points to the same conclusion. At Akhádana a well has been sunk which originally reached a depth of 380 feet but is now nearly filled up; to judge by the debris excavated, this well appears to have been sunk through red sandstones of Vindhyan type with the exception of some 70 feet or so (14 *purus*) which was in pebbly sandstone; but as the well is lined with masonry throughout the portion still open, I was compelled to trust to native information and an inspection of the waste heap.

7. This indicates that the very irregular junction of the Vindhyans and newer beds noticed further east extends for some distance to the west, and any borings put down here would be more likely to strike Vindhyans than coal, at a moderate depth.

[1] R. G. S. of I., XIX, p. 122.

8. I made a short tour into the sandy desert towards Bikhampur in order to see whether the rocks exposed in the wells gave any indication of the presence of coal measures; though I visited two wells in course of construction, I was not fortunate enough to find any fossils, and the rocks were all of a type very similar to those seen among the upper Gondwanas of Jessalmer.

9. Having examined this district, sufficiently to see that no promise of coal could be obtained, I marched towards Jessalmer, intending to visit the reputed coal at Hamira, and then try the unknown country south of Jessalmer. The so-called "coal" of Hamira I found to be merely isolated trunks and fragments of fossil wood in which the structure was still quite distinct; owing to its lightness and the abundance of pyrites, this would be of very little use even if it occurred in quantity, but, owing to its mode of occurrence as fragments scattered through a sandstone matrix, it is quite useless.

10. To the south of Jessalmer I found a descending series of sandstones, in the upper portion of which hard ferruginous bands and patches were abundant, extending as far as Dévikot. To the south of this the beds must turn over, for at Vinjorai ferruginous sandstones again appear and form prominent scarps, here however with a southerly dip.

11. The rocks near Dévikot are, for the most part, a red sandstone, not unlike some of the sandstones near Nagore, but the frequent occurrence of spherical concretions, the general softness of the rock and above all the occasional occurrence of hard ferruginous bands leave but little doubt on my mind that they belong to the Gondwana series. It is impossible to say whether the red colour is original in the rock or merely due to its being formed of the debris of the presumed Vindhyan sandstones; if the former be the case it may indicate the proximity of the red rocks associated with the Bap boulder beds.

12. Hearing that rock was exposed in many places along the eastern frontier of Jessalmer south of the Jessalmer-Pokran road, I examined these outcrops which proved to be nearly all conglomerates and sandstones of unknown age, but as the crystalline rocks appear to be nowhere far from the surface and repeatedly crop out, it would under any circumstances not be advisable to put down borings on this line of country. To the west, rocks are said to be all hidden by sand until the exposures between Jessalmer and Vinjorai are reached.

13. From Jessalmer I crossed over to Pokran to try what might be found there, and was somewhat surprised when a detailed examination of this tract convinced me that the boulder beds there pass under the dark red sandstones which have been regarded as of Vindhyan age. There is no direct proof of the age of these sandstones, nor was I able to determine whether the boulder beds of Bap and Pokran were the same or different, but there seems little room for doubt that the red sandstones of Pokran are continuous with those of Loháwat and overlie the Vindhyan limestone.

14. Towards Jodhpur sandstones, which may or may not belong to the same series as those of Pokran, are largely exposed; frequently they are dark red, composed of well-rounded grains of quartz, but just as often are paler red and by no means infrequently white, the latter beds being usually as hard as the sandstones of Khátu. These latter frequently weather with small rounded bosses and occasionally

include thin bands of black ferruginous sandstone like that seen among the upper gondwana sandstones of Jessalmer.

15. These sandstones have previously been regarded as of Vindhyan age, but if they belong to the same series as the sandstones of Pokran, and if the Pokran boulder beds are the same as those of Báp, they must be much newer than Vindhyan, and might be of lower gondwana age. It is impossible to determine this point with certainty, but the balance of evidence appears to me very strongly against regarding the Jodhpur sandstones as of gondwana age; nor if this could be granted does the prevalence of red beds hold out any promise of the existence of workable coal.

16. It will be seen from the above statement of the essential facts that the prospect of finding workable coal is very small. Along the eastern boundary of the gondwana area upper gondwanas appear to rest unconformably on the boulder beds or even on the old crystalline rocks; there is no reason why the coal measures should not be present, hidden by upper gondwanas and recent sand, but any search for them would be purely speculative. Still, seeing the enormous value that would attach to any deposit of workable coal in this region it may be thought advisable to institute a search; in this case the best plan would be to sink a boring on the crest of the anticlinal between Jessalmer and Vinjorai, about 3 miles south of Devikot, where older beds than are seen to the north or south are exposed; it would be necessary to push this boring to as great a depth as possible or until the crystalline floor was struck.

17. I may point out that as yet only those localities which appeared most promising have been examined; that there is still a considerable area of rock country which has not been visited as the rocks are almost certainly of upper gondwana or even later age, and the discovery that the Pokran boulder beds underlie the sandstones of the Pokran scarp opens out a vista of possibilities which certainly deserve more thorough working out than I was able to give them at the tail end of the working season.

P. S.—Since writing the above I have had an opportunity of examining the rocks of the Salt-Range. Here there is a considerable series of rocks, known as the speckled sandstone group, at whose base there is a boulder bed precisely similar to, and probably the same age as that exposed near Bap. The rocks overlying it are very similar to the neozoic rocks of Jessalmer, except for the absence of the black ferruginous sandstone so common in the latter locality; in spite of this, the lithological relations of the Jessalmer beds with the Speckled sandstone of the Salt-Range are much stronger than with the gondwanas of the peninsular. In the speckled sandstone the only traces of coal known are a few thin papery layers of coaly matter, and it is very probable that there is a similar absence of coal in the Jessalmer rocks. In the absence of special search there can be no certainty on the subject, but, as before remarked, search would be speculative to a degree. I cannot say that there is no coal in Jessalmer, but that is the extreme limit my observations allow me to go to.

CAMP, SUTLEJ VALLEY;
The 31st May 1887.

A Facetted Pebble *from the* Boulder Bed, ("Speckled Sandstone") *of Mount Chel in the* Salt-Range *in the Punjab, by* DR. H. WARTH.

(With 2 plates.)

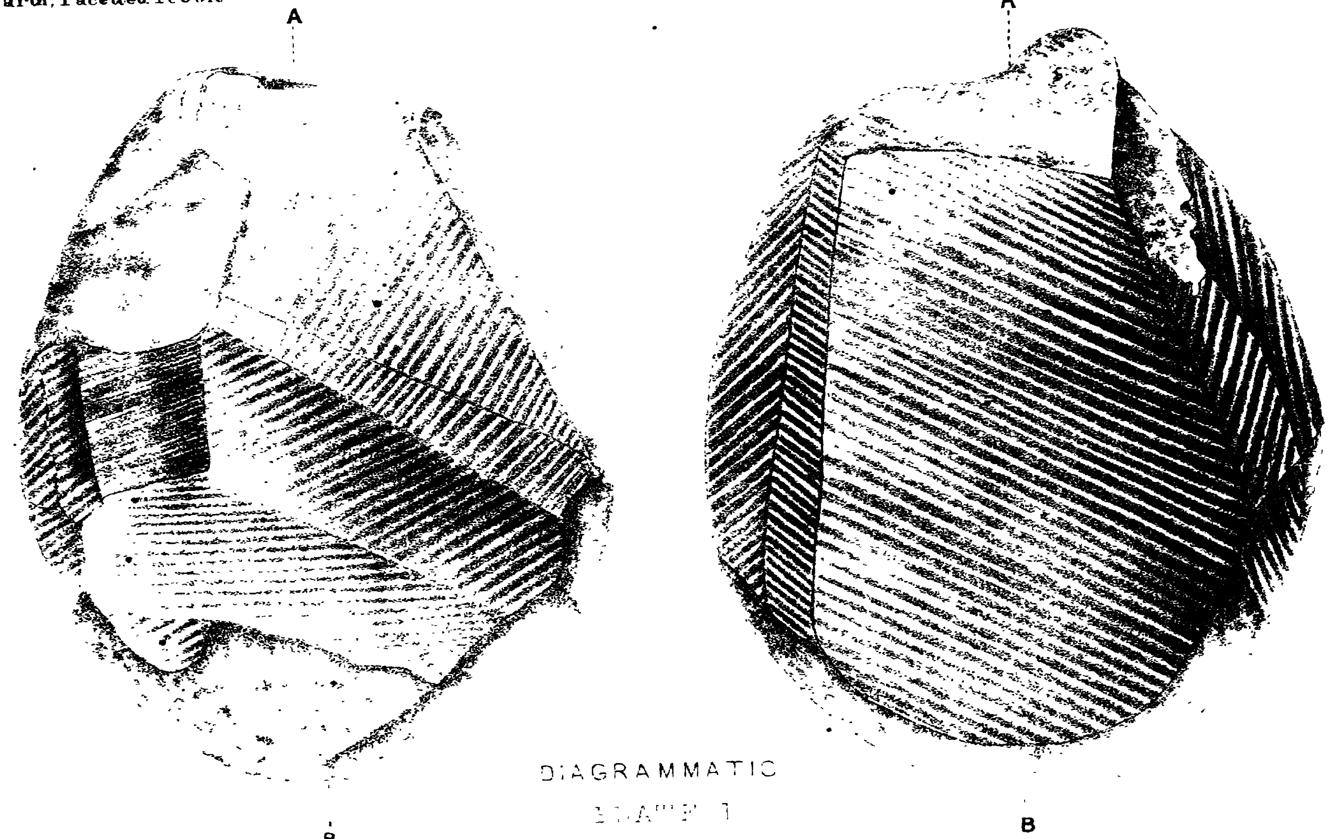
Amongst the facetted pebbles which I found in the Salt-Range is one with such a large number of polished surfaces and such distinct ice scratching that it deserves special description.

The annexed diagram[1] represents two opposite views of the pebble in natural size. The view on the right hand shews the largest of the polished surfaces, which is 10 centimeter's long and 5 centimeters broad. The number of faces is about 20 all counted, the very smallest being about 1 centimeter long and half a centimeter broad. The diagram shows the direction of the scratches on all the faces. The scratches are thicker on the right side of the faces, showing that the stone moved from the left to the right along the respective faces. The pebble must have been pushed by the ice along the floor of the glacier bed, and the whole movement may have lasted several hundred years; the stone during the time turning round so that the polished surfaces were necessarily produced. The angles between the faces vary considerably, and the stone moved also from side to side, so that it did not revolve regularly. But generally speaking it revolved in the mean round the axis A-B of the drawing. The direction in which the stone revolved was most probably such as would make it roll forward, and therefore on the diagram from left to right. Very likely only one total revolution took place during the whole passage of the stone under the glacier, and the faces took therefore each a very long period to form. About one-fifth of the surface is unpolished. The pebble weighs 680 grammes. The rock is red porphyry with a specific gravity equal to 2·566.

The pebble was obtained from the crystalline-boulder bed near the summit of Mount Chel. This mountain rises from the plateau of the eastern Salt-Range to a height of 3,700 feet. Magnesian sandstone forms the summit, but the crystalline-boulder bed which rests here directly on the magnesian sandstone comes close to the summit on the north-eastern slope. The actual boulder-bed, some feet thick, is accompanied by at least 25 feet thickness of greenish mud throughout which boulders are also scattered. The boulder-bed is exposed in section and also parallel with the surface. The surface exposure is more considerable. There is a large mass of boulders and pebbles scattered over several acres of surface on the actual site of the boulder-bed overlying the magnesian sandstone. Only the individual boulders and pebbles have been slightly shifted and re-arranged after the weathering away of the mud. It is on this area that I found about a dozen facetted pebbles, besides many other pebbles and boulders which had only one glaciated surface. I do not remember finding a facetted pebble on the outcrop of the vertical section of the boulder-bed, but this is only natural. When there is only one facetted pebble, amongst

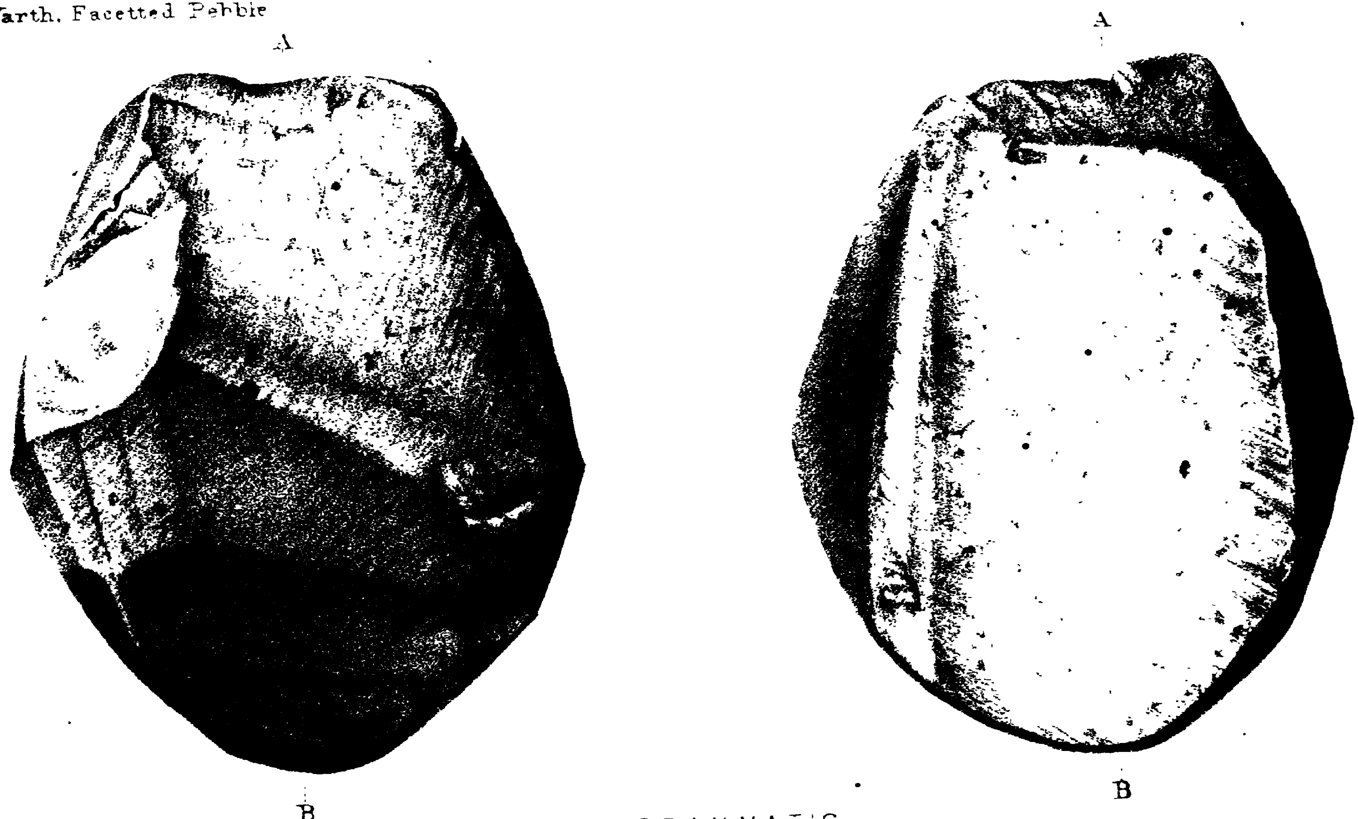
[1] The sketch is very diagrammatic; the scratchings being indicated by very much broader lines than appear on the facets of the specimen; though the actual scratches are very clear and distinct. The second plate is a fairly accurate drawing.—*Ed.*

Warth, Facetted Pebble



DIAGRAMMATIC

Warth. Facetted Pebble



DIAGRAMMATIC
PLATE II

perhaps a thousand others, a large surface is required for search if the search is to be successful. I picked up the specimen under description with my own hand from the area of scattered pebbles. I consider it as a genuine specimen produced by glacier action, deposited by ice transport amongst the boulder-bed, and exposed on the breaking up and weathering of this bed *in situ*. If it was thought possible that a man would have shaped this hard porphyry and thrown it amongst the pebbles, how can we account in the same way for all the other specimens and the partly facetted ones here and in other parts of the Salt-Range. One and all must be the work of nature.

Examination of Nodular Stones *obtained by trawling* off Colombo, *by* E. J. JONES, A.R.S.M., *Geological Survey of India.*

The following account[1] of these stones is reprinted from the Journal of the Asiatic Society, Bengal, as being of more direct interest in these Records:—

"The nodules were obtained during a trawling operation off Colombo in water of 675 fathoms, and are stated to have been found associated with sand and mud, which formed a hard calcareous crust at the bottom of the sea, and a small quantity of which was forwarded with the specimens.

"The stones are irregularly rounded, and vary in shape from almost spherical to roughly cylindrical with rounded ends. The specimens received varied in size from 1—4 inches in length and 1¼—⅜ inch in thickness. Externally, they are rough and mostly have one or two small excrescences of the size of a pin's head, and a few small pittings of about the same size; the colour is dirty light grey.

"On breaking them open, the fractured surface has much the appearance of an ordinary slate without the cleavage, and is of a much darker colour than the exterior. Running along the central line of a long cylindrical one which I broke open, there is a narrow vein of a brownish colour.

"A microscopic examination of a thin slice shewed merely a confused mass of aggregates resembling in their structure that of sphærulites, such as occur in the so-called sphærulitic lavas, with the remains of Foraminifera and Radiolaria disseminated throughout the mass. With ordinary light, little is to be seen except more or less radiating fibrous aggregates, but, as soon as the section is observed between crossed Nicol's prisms, the whole field is seen to be covered with little dark crosses

[1] Natural History Notes from H. M.'s Indian Marine Survey Steamer 'Investigator,' Commander Alfred Carpenter, R.N., Commanding. No. 5. On some Nodular Stones obtained by trawling off Colombo in 675 Fathoms of Water.—By E. J. Jones, A. R. S. M., Geological Survey of India. Journ. Asiatic Society of Bengal, LVI., Part II, No. 2, 1887.

with their limbs parallel to the planes of the prisms, and, on revolving the stage, the limbs of the crosses keep the same orientation whilst the section revolves.

"It is when thus observed that the aggregates are seen to be entirely distinct from one another, as each cross keeps to its one aggregate, and the crosses do not overlap; so that, by revolving the stage, the limit of each aggregate can be determined by tracing the path of the outer end of one of the limbs of the crosses.

"In the volcanic rocks in which this structure is known, it appears to be due to incipient crystallization in a glassy mass; and at first it might be supposed that these masses were of igneous origin. This idea, however, is untenable on account of the remains of Foraminifera (of several species, the most easily recognised of which are the globigerinæ) and Radiolaria which are sparsely scattered through the mass, and, in some cases, enclose a sphærulitic aggregate.

"An indeterminate greenish substance, which probably consists of glauconite, is also seen scattered through the mass.

"The only difference that can be detected between the central vein and the portion between it and the exterior is that the aggregates in the central vein are much larger and the colour brown instead of green, and that it is unacted on by hydrochloric acid, which dissolves out some calcic carbonate from the other portion..

"As mentioned by Mr. Daly in his letter forwarding the nodules, these are very heavy, having a sp. gr. of 3·77 at a temperature of 30° C. as against water of 4° C.

"A qualitative analysis shewed the nodules to consist in great part of baric sulphate together with small quantities of calcic and strontic sulphates, small quantities of calcic and magnesic phosphates, aluminic silicate, calcic carbonate, and traces of iron, sodium, and manganese.

"Not having the time to devote to a complete quantitative analysis, I made, in order to arrive at an approximate estimate of the proportion of baric sulphate present, a determination of the sulphuric acid. An average sample from two of the nodules powdered and dried at 100°C. gave 82·5% of baric sulphate, the whole SO_2Ho_2 being calculated as SO_2Bao''.

"This result is, however, of course too high, as a small quantity of the SO_2Ho_2 is combined with Ca. and Sr. in the form of calcic and strontic sulphates, though, from the results of the qualitative analysis, it is probably not much too high; and we may, I think, safely take 75% as the percentage of baric sulphate present.

"In order to see whether the material was derived from the mud in which the nodules occur, and which also contained Foraminifera, I made a qualitative analysis of the mud; and found it to consist mainly of aluminic silicate, with small quantities of calcic carbonate, some iron, and a trace of manganese; there was also a trace of an alkaline earth which was not removed by boiling with hydrochloric acid and subsequent washing, but this, on spectroscopic examination, shewed itself to be lime.

"In spite of the negative result of the analysis of the mud, I am inclined to think, from the presence of the Foraminifera both in the mud and enclosed in the nodules, that the latter have been formed at the bottom of the sea either at the spot where they were found or at no great distance therefrom, though it is difficult to imagine how the material was obtained, but it is possible that a careful analysis of a larger

quantity of the mud would reveal a trace of Barium, for sea-water contains a slight trace of this element.

" I cannot at present call to mind any instance of sphærulitic structure occurring without the aid of heat.

" In volcanic lavas and in artificial glasses, it may be regarded as concretionary, or as resulting from incipient crystallization or devitrification around certain points or nuclei. The nuclei when they exist consist either of a granule or a minute crystal or crystallite, but most commonly no nucleus is discernible.[1]

" In this case, however, it would seem, that it must be due to slow segregative action; and, baric sulphate being very slightly soluble in water, the deposition would be very slow and may have been to some extent crystalline, at any rate sufficiently so to produce the same effect as incipient crystallization from a glassy mass.

[1] Rutley's Study of Rocks, p. 183.

Yours sincerely
W. B. [illegible]

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1888. [May.

Award *of the* Wollaston Gold Medal, Geological Society of London, 1888.

Annual General Meeting, February 17th, 1888. Professor J. W. Judd, F.R.S., President, in the Chair.

In presenting the Wollaston Gold Medal to Mr. Henry Benedict Medlicott, M.A., F.R.S., late Director of the Geological Survey of India, the President addressed him as follows:—

"Mr. Medlicott,—The Council of this Society are not unmindful of the fact that many of our Fellows are engaged in the promotion of Geological Science in every part of a vast Empire; in awarding to you the highest honour which is at their disposal, they are following a precedent which was established more than fifty years ago, by the presentation of the Wollaston Medal to Cautley and Falconer. In that great Indian dominion where those famous geologists carried on their important researches, you commenced your labours as far back as the year 1854; and for more than a third of a century you have continued the almost incessant exertions which have led to very important additions to our knowledge, often obtained only at the price of severe hardships, and at the risk of serious dangers. During the last eleven years you have occupied the important and responsible position of Director of the Indian Survey; and it is to your administrative ability in that position that we owe many of the valuable results obtained by that Survey in recent years; more especially are we indebted to you, and to our Secretary, Dr. Blanford, for that useful Compendium of Indian Geology which has now become indispensable to all students of our science. We feel it to be singularly appropriate that we are able to make this award to you just at the time that you return to your native country for the rest you have so well earned."

"Mr. Medlicott replied:—Mr. President,—The award of the Wollaston medal by the Geological Society is the most gratifying distinction that a geologist can receive. It is only as a recognition of devotion to our science that I can venture to accept so great an honour. My work has been chiefly in combination with others, and it gives me much consolation to think that my colleagues of the Geological Survey of India will share in this reward, and will appreciate it."

The Dharwar System, *the* Chief Auriferous rock series *in* South India, *by* R. B. FOOTE, F.G.S., *Superintendent, Geological Survey of India.* (With Map.)

The promising development of the gold mining industry during the last five years having gone far to undo the mischievous effects of the wild gold speculation of previous years, greatly increased attention has been devoted to the auriferous rocks in Mysore, and the adjoining districts of the Madras and Bombay Presidencies and the Nizam's Dominions. A proof of this is furnished by the fact that a London publishing firm reproduced the map which I had given in illustration of my paper on "A traverse across some gold fields of Mysore," which appeared in the Records, Geological Survey of India (Vol. XV, part 4, 1882). Since the publication of that paper my official duties have taken me over large tracts occupied by the auriferous rocks both in the Ceded Districts (Bellary, Anantapur, &c.), and in Mysore; especially in the latter. Some of the information gathered about the auriferous rocks in the Ceded Districts was made public in the "Notes" published in 1886, "On the geology of parts of the Bellary and Anantapur Districts" (Records, Geological Survey of India, Vol. XIX, part 2). The additional facts collected as to the geology of the Mysore country were obtained during a visit to different parts of that State, made by desire of the Durbar with the object of my reporting on the auriferous tracts known to exist there, and about which separate reports had been previously drawn up by Messrs. Lavelle and Marsh. On completing this tour, which occupied the months of February, March, April and part of May of last year, I drew up a "Report on the Mysore Auriferous Tracts," which was published among the selections from the Records of the Mysore Government for 1887. My report was accompanied by a map showing the distribution of the auriferous rocks or "Dharwars" as then ascertained. This map, too, only claimed to be a sketch, and, as such, subject to modification when the country comes to be regularly surveyed. It was, however, a great advance on the first map published in 1882. In this report the subject of the auriferous rocks had to be dealt with from a purely economic point of view, and for non-geological readers, all technical expressions were, therefore, as far as possible banished from it, and no attempt made to illustrate the different features of purely geological interest. These are dealt with in the present paper. The map which accompanies it is on the same scale as that illustrating my "Traverse across Mysore" (Records, Geological Survey of India, Vol. XV, p. 4, 1882), and a comparison of the two will show that a very real advance has been made in the interval in ascertaining the extent and distribution of the Dharwar rocks. The map, however, is only put forward as an improved sketch to be superseded in its turn. Large additions to the extent of the Dharwar system will certainly have to be made on the map, as the geology of south and west Mysore, and the adjoining districts of South Canara, Coorg and Coimbatore is worked out. In the Ceded Districts, too, and most probably on the western side of the Dharwar Districts also, considerable areas of the Dharwar rocks have yet to be separated from the Gneissic system among which they were formerly reckoned.

The Dharwar rocks form a very well marked series (or system), consisting mainly of Schistose rocks (hornblendic, chloritic and argillitic) with associated,

more or less hæmatitic quartzites and numerous contemporaneous trap flows. In many parts of the areas occupied by these rocks occur quartz reefs and veins which are auriferous, indeed all the more important auriferous tracts as yet known in South India lie within such areas, and hence the rocks composing them have come to be called the auriferous series. The Kolar gold field unquestionably occurs in an outlying band of the Dharwar system, and so also the Honnabetta, Chicknayakanhalli, Kotemaradi, Honnamaradi, Halékal gudda, Malibennur, Chiranhálli, Honnahatti auriferous tracts and the Honnali gold field (Kudri konda and Palvanhalli) in Mysore, and the Dambal gold field, in Dharwar District, which occur in one or other of the great bands. The majority, if not all the fifteen outlying auriferous localities, forming the west central group of my Mysore Report are also situated on detached areas or outliers of the Dharwars.

The name Dharwar why selected.

The name chosen for this great series of rocks, the "Dharwars," was selected on well recognized principles of geological nomenclature, from the district in which the separation into a distinct and separate system of the Schistose rocks was first recognized. Till then they had been grouped as part of the great South Indian Gneissic system. The necessity for such separation was pointed out by me in my memoir on the South Mahratta country (Memoirs, Geological Survey of India, Vol. XII, 1876), but I waited for further evidence of the stratigraphical relation of the Schistose series to the far more crystalline gneissics, and this was obtained during my traverse across Mysore in 1881, and by an examination of the rocks in the Sandur and Bellary hills in 1884-85. The Schistose rocks are very largely and clearly developed in Dharwar District, and the well known town of Dharwar stands on them. All things considered, no other local name seemed to have so many points in its favour and the name of Dharwar was therefore given to the schistose, or auriferous rock system.

Distribution of the Dharwar rocks.

A glance at the map will explain the distribution of the Dharwar rocks far more fully than would many pages of writing. The reader is therefore referred to the map, where it will be seen that the rocks occur in three great bands, continuous for great distances, between which, and to the north and east of which, are a considerable number of irregular patches and short bands, mostly of small size, which will be enumerated and in part described further on. The three great bands have been called respectively the Dharwar-Shimoga band (the most westerly of all at present known); the Dambal-Chiknayakkan-halli band, and the Pennér-Haggari band, which includes the great Hunugunda band extending from the Tungabhadra, north-west across the Raichur Doab up to the Kistna. Between the Dharwar-Shimoga and the Dambal-Chiknayakkan-halli bands lies (on the right bank of the Tungabhadra) a large patch, at the south end of which stands the large village of Kunchur (Coonchoor); only the extreme north end of this has been actually visited; it cannot therefore be described, though the bare nature of the hills made it easy enough to see that they did not consist of granites or gneisses. In the southern part of the space between the two great bands just named lies a considerable number of small patches, mostly narrow and band-like in shape, of which three may be named as important geologically. These are the Taggadur-

The great bands.

Minor bands and patches.

betta patch in latitude 13° 3′ N.—and longitude 76° 30′ E., the Bellibetta band, 16 miles to the south, and Honnabetta 24 miles south-east of Taggadurbetta. Twenty miles south of Bellibetta lies a group of three small auriferous patches which I will call the Sonnahalli group (to be described further on), and 22 miles east of this group is a solitary small patch, at Holgere, the most southerly auriferous tract which came under my notice in Mysore. This is a doubtful outlier of the Dharwars.

The Sandur and Copper mountain tract.

Between the Dambal—Chiknayakkan-halli band and the Pennér-Haggari band lies a rather large and very important tract of the Dharwars which here form the Sandur hills and the Bellary Copper mountain range, a group of hills in which the geological characteristics of this system may be studied to great advantage.

Bands north of the Pennér-Haggari band.

To the north of the Pennér-Haggari band in the country between the Tungabhadra and Kistna, are several short but important bands which will have to be described separately further on.

Lastly, must be noticed the band forming the Kolar gold-field, which lies far to the eastward of the southern part (as at present known) of the Dambal-Chiknayakkanhalli band. When the country intervening between it and the known part of the Pennér-Haggari band shall have been examined it is very probable that a connection will be traceable between the two bands.

Of the several bands and patches above enumerated, only those lying within the Bellary district proper, and a few miles of the Pennér-Haggari band in Anantapur district have been closely surveyed with the object of specially studying their structure and petrology. The Kolar, Honnali and Dambal gold-fields have also been studied carefully, but no good maps showing their topographical features fully were available, and in the two former so much of the surface is covered with cotton soil that very many points of difficulty could not be solved satisfactorily.

Origin of the schistose bands.

The occurrence of the Dharwar rocks over the face of the gneissic systems in such remarkable bands, or portions of bands, is a feature which at once arrests the attention and demands explanation. The explanation is that the Dharwars, as now seen, are the remains of a great sedimentary series which covered a very large area in what now forms the peninsula of India. The periods of sedimentary deposition were interrupted by periods of volcanic activity during which great flows of contemporaneous trap were poured out. Many such flows were formed in different parts of the Dharwar area, as in that which now forms the Sandur and Bellary hills, and further to the south-west the hills south of Chitaldrug and the Bababuden mountains.

The Dharwar rocks were at a very remote geological period exposed to vast lateral pressure, by which they were crumpled into great folds, which were then exposed to great denuding action, and largely eroded. This took place anterior to the deposition of the Kadapa and Kaladgi basins, which belong to the upper transition group. Both basins were deposited unconformably on the upturned, and greatly contorted and eroded beds of the Dharwar system. The great jaspery hæmatite beds of the Dharwar system furnished the bright coloured jasper pebbles which are so striking a feature in the basement and other conglomerates of the Kadapa system.

The forces which caused the great crumpling of the Dharwar rocks had, of necessity, also much effect on the underlying gneissic rocks; and in various places

induced a parallelism of folds which gives locally great semblance of conformability. The section of the gneiss rocks exposed south of the southern end of the Sandur tract, shows the gneiss to have been affected by an anterior process of crushing from pressure, acting in a more or less east and west direction. This is noteworthy, as it shows that the peninsula was affected at no less than four periods by great, approximately east to west or west to east, thrusts; the two just noted, and two later ones, by which the Kadapa and Karnul rocks were respectively crumpled up into the great foldings they now show. Of these, the last would seem to have been the least energetic.

Only a brief description of the chief petrographical characters of the Dharwar rocks can now be given; the full description of the members of the system which occur within the limits of the Bellary and Anantapur country must be reserved till the final Memoir on that tract comes to be written, while those of the Dharwar rocks lying in other tracts will have to await the times when they may have been studied by other geological workers.

DESCRIPTION OF THE SEVERAL BANDS AND PATCHES OF THE DHARWAR SYSTEM.

I.—The Dharwar-Shimoga band.

Northern group of inliers.

This great band of the Schistose rocks appears at its northern extremity (in the Belgaum District) in several small inliers exposed by the denudation of the overlying Kaladgi rocks and Deccan Trap flows. These inliers present nothing very noteworthy, and may be dismissed with a mere enumeration. They are seven in number. The most northerly is the Gokak inlier covering some ten square miles around the town of Gokak. The second, or Kelvi inlier lies about a mile south of the first. Four miles to the S. W. of the Gokak inlier is the Padshapur inlier, a rudely cruciform valley, cut through the Kaladgi quartzites. In this the Dharwars are very badly seen, owing to the extensive alluvial deposits of the small Markandi river, a tributary of the Gatprabbha. The Dharwars are similarly very badly displayed in the small inlier exposed on the north side of the valley of the Belgaum nullah (some four miles N. E. of that town), which nullah forms the most southerly branch of the Markandi river. The other three inliers may be called the Wannur, Budnur and Seedapur inliers, from the principal villages within their limits, or close to them. The northern extremity of the great band south of the edge of the Deccan trap area is also very badly exposed; the surface of the schists, and indeed of the whole Sampgaum Taluq, being greatly masked by extensive sheets of cotton soil. The rocks chiefly seen are bands of hæmatitic quartzite, forming low bare ridges, which are in many cases traceable for many miles in extent; between them are beds of chloritic schist, generally of pale green colour. Argillites occur also, and are in parts considerably hæmatitic in their mineral character. Contemporaneous trap is also to be seen in the valley of the Belowaddi nullah.

North end of the main bands.

Near to Byl Hongal and Belowaddi, the sands of several streams are reputed auriferous, and used formerly to be washed for gold; so also the nullah at Hatti Katti near Belowaddi. The accounts given of the amount of gold found in this quarter are rather conflicting, the earlier records representing it as much more important than at present. All the enquiries made by myself on the spot, and for me by the local authorities, showed the gold industry to be practically extinct. Extremely few traces of quartz-reefs are to be seen on cursory inspection, but the country is closely covered by cotton soil and by great accumulation of hæmatite derived from the great beds of hæmatitic jaspery quartzite which occur so numerously. I followed the Dharwar rocks from the valley of the Malprabbha at Sangoli southward to Tegur, and thence south-eastward to Dharwar town. The schists, argillites and hæmatitic bands continue all the way, and as far as the eye can reach, on either side of the road. The schistose rocks are, in their appearance, so utterly unlike the gneisses and granites flanking the great bands, that it is generally very easy to recognize the character of hills and ridges when seen in strong sun light from distances of many miles even, more especially when the ridges are continuous. The extreme bareness of vegetation of most of the ridges also greatly facilitates the recognition of geological features from long distances. The northern part of the Dharwar-Shimoga band forms, roughly speaking, the western boundary of the great black plain, the regur flat of Dharwar District. From Dharwar, I followed the band down to Hubli, and from high ground there could see it extending miles away to the S.S.E. Newbold describes a great schistose band crossed by him in travelling from Sirci (N. Canara) to Gadag (Gudduck); this can only be the extension of the Dharwar-Shimoga band. At Harihar it crosses the Tungabhadra, and from here I have either followed it personally or traced it by the eye in unmistakable beds over by far the greater part of the area which I have represented it as occupying. Some parts of it I have coloured in as of Dharwar age, from the conviction that the beds I have crossed and identified as forming the northern ends of great ridges, will assuredly be found to extend as far as those ridges are seen to stretch without any change in their physical characters and appearance. The excellent delineation of the topographical characters of such ridges in the 1-inch maps of the Topographical Survey of Mysore, assures me that my inference of such extensions of the Dharwar rocks is quite justifiable, and I feel assured that my inferences will be confirmed. This is specially the case with the tract lying between the Tunga and the Bhadra rivers. Of the southerly extension and strike of the Dharwar rocks in the great ridges south of Kumsi there can be no doubt. As seen from the Honnahatti hill, near Lakki-valli, the same characters of the continuous ridges is seen to extend far to the southward, and the same continuous character of orographic feature strikes the eye forcibly when looking south-westward from Kalhattigiri peak on the Bababuden mountain. Unless the topographical featdres of the mountains around Kalasi peak are utterly misleading, and from my experience of the remarkable agreement of topographical feature and geological formation over very great part of Mysore, I cannot believe that to be the case, the Dharwars extend far southward of what I have indicated, and form the

Gold washings in Sampgaum Taluq.

Near Dharwar.

South of the Tungabhadra.

Near Lakki-valli.

great mass of Ballalraiyandrug, and extend still further south, down into the low country of South Canara.

The representation I have given of the Dharwar rocks around the Honnali, Saulunga, Shimoga and Tarikere gneissic inliers is, I feel convinced, a near approximation to the truth. The eastern part of the north boundary, and the southern boundary of the Honnali gneiss inlier, I lay down from actual survey. The eastern boundary is formed by bold hills whose western base must coincide very nearly with my lines. Of the Shimoga inlier, I have followed more than half the boundary lines, and the same was the case with the Tarikere inlier. To the east of the Shimoga inlier, I think it possible that an inlier, or some small inliers, may occur between Channagiri and Tarikere, and so also with regard to the tract between Belur and Banavar further to the south: but this is merely a surmise.

Gneissic inliers in the central part of the band.

To the west and east of Hassan, I have shown two narrow bands of Dharwar rocks extending southward, neither of which I had the opportunity of following to its extremity. Of the extension of the western band I could not form any opinion; that of the eastern band will, I expect, be found running down nearly to the Cauvery.

From the very rapid character of my journeying over the central part of the Dharwar-Shimoga schist band (the Honnali gold-field excepted[1]) the information I gathered was necessarily fragmentary, but nevertheless it throws much light on the petrographical structure of the band, and is therefore worthy of record, and I will give my observations in geographical order proceeding from north to south.

At Harihar the Dharwars are greatly masked by the alluvium of the Tungabhadra, and by the almost ubiquitous cotton soil. Large banks of coarse shingle occur both north and south of the town. Underlying the shingle, schist crops up at intervals along the road to Mallé-Bennur. South of the Haridra (the little river which has been dammed back to form the great Sulekerra tank), a considerable show of contemporaneous trap appears through the cotton soil spreads.

At Mallé-Bennur a remarkable bed of coarsely brecciated quartzite makes a great show, forming a conspicuous ridge which has been utilized to form great part of the bund of a small, but deep tank. South of the tank the breccia bed runs up into and forms the backbone of a much more important ridge. It becomes increasingly hæmatitic and less and less brecciated as followed southward. The dip of this bed is eastward.

At Mallé-Bennur.

Underlying this brecciated hæmatitic band is a considerable thickness of chloritic schists, in the upper part of which are many laminæ, and small nests of crystalline limestone. A very good show of gold was found on washing the sand of a small stream which flows into the tank from the western slope of the ridge just mentioned. The gold is probably derived from some of the many small blue quartz veins cutting the chlorite schist. No large reefs were visible. Underlying the schists is a bed of trap apparently of contemporaneous origin. To the west of the trap flow, but not seen in contact, is a quartzite so much altered by crushing and weathering that it has in parts assumed quite a gneissoid appearance. This is followed downwards,

[1] The Honnali gold-field so called, which formed the western extremity of my traverse across Mysore in 1881,—lies along the south side of the Honnali gneiss inlier. The two principal mines that have been opened in it are those of Kudri Konda and Palvanhalli.

(stratigraphically) by a thick band of dark schist, chiefly argillitic, which in its turn is underlaid by a great thickness of pale green and grey schists of variable character, but chiefly chlorito-micaceous. Small beds of quartzite are intercalated here and there, and veins of white and pale bluish quartz are numerous but very irregular in size and shape. These beds form the main mass of the Hanuman-betta hill group.

The schist series here makes a great curve, the western part trending west and crossing the Tungabhadra some 15 miles to the westward, while the south-eastern part trends south, and may equally be followed by the eye for many miles, forming very considerable hills and ridges.

The Honnali Gneiss inlier.

On getting down to the low country at the south end of the ghat leading to Honnali, an inlier of granite gneiss is reached which occupies the greater part of the valley of the Tungabadra, between the town and the gold-field known as the Honnali gold-field. The western extension of the beds which cross the Tungabhadra north of Honnali town forms a band of hills of considerable importance which can be seen to stretch away north-westward for a great distance.

The south-west side of the inlier is bounded by a great fault by which the gneissic rocks have been brought up and exposed over a large area by the erosion of the Dharwar beds which formerly covered them. The fault extends along the whole south-western side of the inlier and crosses the Tungabhadra. I did not follow the fault across the river. The eastern boundary of the inlier, like the northern one, is a true erosion boundary.

Honnali gold-field.

The belt of country on the south-west side of the inlier which constitutes the Honnali gold-field was carefully examined by me in 1881, and in part re-examined last year. The northern part of the belt is occupied by a great thickness of chloritic schists, underlaid to the south by a great mass of quartzites and conglomerates with some argillites. These, from their superior hardness, have been much less denuded than the chloritic beds and form, especially in the north-west part of the belt, hilly ridges of considerable height. The Honnali gold-field is divided by the Nyamti nullah into divisions of pretty equal length and breadth, which may be conveniently called the Kudrikonda and Palvanhalli divisions, after the two important gold mines which have been already opened on them, the former to the west, the latter to the east, of the Nyamti nullah.

In the Kudrikonda, or western division, chloritic schists only show in the plains, but in the eastern division, east of Palvanhalli mine, numerous intercalated quartzites, quartzite sandstones, and gritty beds appear, and rise into good-sized hills as they are followed eastward. The great contortion these beds have undergone has caused considerable local metamorphism, and the true detrital character of the gritty beds is in many places not apparent; where, however, they are coarse in texture, and approach in character to pebbly beds, their true origin can be recognized at once. This is the case also with regard to the great beds of conglomerate and flaggy quartzite in the lofty Kalwa-Rangan-betta ridge which forms the south side of the Kudrikonda division of the gold-field.

The Saulonga inlier.

To the south of the Kalwa-Rangan-betta ridge, lies another inlier of gneiss of considerably smaller area than the Honnali inlier just referred to. It appears to owe its origin to an important fault

running north-west along its southern boundary, and somewhat parallel with the great fault which forms the south-west side of the Honnali inlier. Owing to the thickness of the soil and extensive jungle, the gneissic rocks are but little seen at the eastern end of this inlier where crossed at Saulonga by the high road from Honnali to Kumsi. Near the centre of the inlier however, some small rocky hills of granite gneiss show up sufficiently to be recognized from the top of Kalwa-Rangan-betta. Any one not having seen these might easily cross the inlier at Saulonga without becoming aware of its existence.

The Dharwar rocks are very little exposed in the Kumsi hills which lie south of this Saulonga gneiss inlier, owing to the dense forest covering them, but the shape of the hills clearly indicates the continuance westward of the beds which form the hilly tract along the northern side of the Shimoga gneiss inlier, the largest of the whole group of four forming such a striking geological feature in the north-western corner of the Mysore territory. At the north-western end of the inlier, some of the beds, which in the Kumsi hills have an east-to-west strike, trend south-westward and form the great ridges forming the Shankar-gudda and Kormur-gudda hills, which may be seen to extend for many miles southward. Another part of these beds trends north-west in the direction of Sorab, but they have not been followed beyond a point a little to the north-east of Anantapur.

The Shimoga inlier.

South of the Saulonga inlier lies a very much larger one, in the centre of which stands the town of Shimoga, the south-western boundary of which is also formed by one or more faults running north-west to south-east, which are very apparent even on cursory examination, but the extremities of the fault line are obscure, owing to the extensive jungle prevailing to the south of Kumsi and north-west of Tarikere. To the south of the inlier occurs the promising auriferous locality known as Honnahatti, where some noteworthy old workings were found by me in chloritic schists traversed by well-marked quartz reefs. The chloritic schists strike north-west to south-east with a steep dip to the north-east. The Honnahatti workings stand on the narrow strip of the Dharwar rocks, which separates the Shimoga inlier from the Tarikere inlier, the last and most southerly of the group of four. Washings in the small stream draining the south side of Honnahatti gave very fine shows of gold.[1]

[1] NOTE.—A special feature demanding notice in the western half of the Shimoga inlier, and still more striking over the gneissic tract of the Dharwars near Anantapur is the development of lateritic rock which covers the surface almost ubiquitously and to considerable depth, rendering it extremely difficult to find any outcrop of the underlying older rock. I have not attempted to show the laterite on my map separately from the gneiss on which it mainly lies, as my brief visit to this north-west corner of Mysore did not afford me time to determine the relationship between the rocks. I did not see enough of the laterite to feel satisfied as to its being of true detrital origin or merely a product of weathering, as is much of the laterite on the southern parts of the Deccan trap described in my South Mahratta Report (Memoirs, Geological Survey of India, Vol. XII, 1876). The laterite which I am (so far as my observation goes up to the present) inclined to regard as formed by weather action, constitutes a nearly uniform cover to the whole country, whether it be flat or hilly, with a generally pale, reddish, more or less clayey surface, which affords but little nourishment to vegetation. The grasses, especially seem to thrive very badly and are very coarse in quality, a chief reason probably why cattle and sheep succeed so badly in the Malanad, as the forest clad, western portion of Mysore is locally designated by the natives.

The Tarikere gneiss inlier.

The existence of a great fault along the south-western boundary of the Tarikere gneiss inlier has not been proved, but I have no doubt it will be shown to exist whenever the country may be geologically surveyed. The rocks are very little exposed either in the area of the inlier or in the ridges of Dharwar age which surround it. Extensive jungle and great spreads of soil effectually hide the rocks in most places east of the Tarikere inlier; a change takes place in the nature of the country, the great jungles are met with no longer, and the slopes of the hills being exposed to unchecked denudation, show an abundance of outcrops of all kinds.

Kaldrug Conglomerates.

Along the south side of valley running eastward of Tarikere are numerous outcrops of quartzite with schists; and near the eastern end of the valley appear great outcrops of an extraordinary conglomerate of extreme coarseness. The pebbles, often approaching in size to small boulders, consist of granite or compact granite gneiss cemented together in a foliated chloritic matrix. The beds culminate in a considerable hill, called the Kaldrug in the Indian Atlas (sheet 57), which presents a most rugged appearance. The beds east of the conglomerate are largely quartzites which form a high ridge with a great cliffy scarp on the eastern face of "Coancancul" peak (Atlas sheet No. 60). East of these, again, comes a great thickness of pale chloritic schists. These schists extend north of the Tarikere valley, and form the hills north-west of Ajimpur, and extending up to and beyond Chiranhalli, where washings in the small streams cutting across them yielded very satisfactory indications of gold. The conglomerate beds appear also to be represented on the north side of the Tarikere valley, for a long line of excessively rugged outcrops shows to the west of the schistose band in a strictly corresponding position. The Chiranhalli pale chlorites are largely mixed with pale talcose schists, both of which rocks contain very numerous crystals, mostly small, of cubical iron pyrites, and further numerous octahedra of magnetic iron. These latter are locally distributed.

Santaveri Section.

To return to the west end of the Tarikere valley, a large development of chloritic schists occurs extending southward for a considerable distance. South of these, and underlying (?) them, come great thickness of trap flows, which form great part of the great Santaveri spur, joining the lofty Dodda Bala Sidderu mountain (5,136 feet high) with the yet higher mass of the Bababuden mountains, which here attain an elevation of 6,155′ in the Kalhattigiri peak. The trapflows are disposed in a very flat anticlinal curve, and to the west are seen to be overlaid by a great thickness of dark schists (? argillites) with hæmatitic bands and quartzites overlying them again. These schistose beds are splendidly exposed in the great scarp which runs all along the eastern side of the Bababuden mountains from north of Kalhattigiri to south-west of Mallaingiri, the most southerly peak of the mass (6,317′) and the highest point in Mysore State.

Basement beds near Chik Magalur and Sigegudda.

To the south of Chik Magalur, and again to the south-west of the Sigegudda mountain, north-west of Hassan, the basement bed of the Dharwar system is formed by pebbly quartzites dipping north- and north-east respectively. The latter beds are seen to extend southward along the western side of the narrowing band of Dharwars described above (page 45) as running north-westward of Hassan. Quartzites overlaid by

schists form the narrow band of Dharwars which runs south from near Harnhalli close to Narsapur, and constitutes the southern extremity as far as yet known of the Dharwar-Shimoga band.

II.—*The Dambal—Chiknayakkanhalli Band.*

As in the case of the Dharwar-Shimoga band, the northern extremity of this tract of Dharwar rocks is very badly seen, owing to the vast waste spreads of cotton soil which cover the great plain forming the eastern half of the Dharwar District. The only exposures of any importance of the Dharwar rocks in this part, are beds of schist and hæmatite in the scarps of the Nargund and Chick Nargund hills below the cappings of quartzite of the Kaladgi series (Kadapas) which form the summit plateaus on both hills and rest on the Dharwar beds in the most marked unconformity. The Dharwar beds are upturned at high angles and dip 50°—70° east by north in the Nargund hill, the quartzite capping of which, a finely scarped plateau, is approximately horizontal. At Chick Nargund the quartzite capping has a dip northward, while the schist beds on which it rests have a strong dip to east by north.

Sections at Nargund and Chick Nargund.

Nearly equidistant from the two Nargund hills to the westward, a patch of contemporaneous trap rises above the cotton soil surface and forms a blocky ridge about 3 miles long by half to three-quarters of a mile wide. The rock is a diorite (?) of dark greenish colour.

Asmatti Trap-flow.

I did not follow the band up from Nargund, but marched south-west to Naulgund where there is a hill capped by a singular inclined plateau of a rock which may be a quartzite, very highly metamorphosed, but may also represent a run of the brecciated quartz which occurs so commonly in the granite gneiss area, adjoining and throughout the granitoid areas of the Ceded Districts. The plateau inclines to the north at an angle of about 45° which is a lower dip by far than observed elsewhere in any quartz run of unquestioned character,—still on the petrographic evidence of the rock itself it appears rather to be such a quartz run, greatly depressed by some local faulting, or other, than an altered quartzite of the Dharwar system. No exposure of the Dharwars was observed by me in the bed of the Bennihalla, the large stream which after draining this region, falls into the Malprabbha near Badami town. Whether any outcrops of the rocks occur between the Bennihalla and the northern extremity of the Dambal hills near Gadag (Gudduck) is uncertain; but there is every reason to suppose that a strong band of them exists under the cotton-soil spread, for a great thickness of chloritic schists rises out of the plain already a little to the north of the high road leading from Gadag (Gudduck) to Hubli. South of the road two great bands of hæmatite schist stand out conspicuously among the other softer schistose rocks, and may be followed continuously for ten or twelve miles south-eastward.

Naulgund hill.

Chloritic schists near Gadag.

Further south, another apparently underlying hæmatite band with associated, chloritic, hornblendic, micaceous schists and crystalline limestones forms an anticlinal arch and is overlaid to the westward by another hæmatitic band, and this again by two

The Dambal gold-field.

others with associated argillites of reddish-buff or mottled whitish colours. These are greatly affected by cleavage, which completely obscures the bedding in many places, and renders their stratigraphical relations to the rocks next succeeding to the westward very problematic. This next series consists of chloritic and hornblendic beds intimately associated with a massive dioritic (?) rock, probably a contemporaneous trap, which covers a belt of country some 4 or 5 miles wide, and abuts to the westward against the granite gneiss which here forms a broad band extending westwards till it is overlaid by the eastern edge of the Dharwar-Shimoga band near Luxmaishwar, as described by Newbold.[1] The two most westerly beds of the hæmatite series form the mass of the Kappatgode, the centre and highest point of the plexus of hills which occupies the southern part of the gold-field.[2]

Surtur trap flow.

The auriferous nature of the rocks of the Dambal gold-field has long been known, and the surface of several of the quartz reefs been broken up by native miners at some former period. Gold washing is still followed by a few "Jalagars," professional gold washers, particularly in the larger streams rising on the area occupied by the contemporaneous trap above mentioned. The two largest nullahs, known respectively as the Surtur and Dhoni nullahs, from the principal villages near which they flow, are the richest in gold sand. The quantity of gold obtained is small, too small indeed to tempt many to engage in washing for it. Quartz reefs occur in all parts of the gold-field, but those found in the western part among the chloritic and argillaceous schists adjoining the trap area, are the best defined, and have received most attention from the old miners. They are doubtless the principal source of the gold obtained there. The only reef from which I obtained free gold was one of this set. It lies on the eastern slope of a ridge about 8 miles due west of Dambal, and has a north by west, south by east course, with a hade of from 40° to 50° east, and is about half a mile long.

The auriferous reefs.

Hattikatti reef.

A few small excavations hardly worthy of the name of pits had been sunk along the eastern side of the reef at some time prior to my visit, but I could not obtain any satisfactory information as to whom they had been sunk by. As already mentioned, I obtained no gold from any of the other reefs, and the indications of gold from washings in the streams draining the sites of the other groups of reefs to the eastward of the Kappatgode hill were far from encouraging.

The quartz of the Hattikatti reef from which I got the specimen of free gold, and of the majority of the reefs throughout was of the ordinary kind, white or milky in colour, but very largely iron-stained in parts. The group of reefs occurring south of the village of Dhoni on the east side of the Kappatgode[3] differs from all the others in consisting of distinctly bluish, or deep grey, diaphanous quartz, with a few enclosed scales of white or pale mica.

The Dhoni groups of reefs.

[1] In his paper on the Geology of the South Mahratta Country, and elsewhere.

[2] A more detailed account of the rocks forming the Dambal will be found in Part 4, Vol. VII of the Records, Geological Survey of India, 1874, in my paper on the Auriferous Rocks of the Dambal Hills, Dharwar District.

[3] Shown in the map accompanying my paper referred to above.

The reefs, excepting that of Hattikatti, and two others a little distance to the S. W., showed no sulphides of any kind, and those three yielded only a very few cubical crystals of iron pyrites. The argillites and chloritic schists, however, show great quantities of cubical crystals of that mineral converted into limonite by pseudomorphism.

The different members of the Dharwar system occurring in the Dambal area are seen to extend far south in the band of hills stretching away down to the valley of the Tungabhadra, which they cross and re-appear on the south side in the Haddagalli taluq of the Bellary District. The intermediate part of the band has not yet been examined, but being very bare of vegetation it is very easy to see the disposition of the outer beds on either side from a moderate distance. To the east of the band, the beds there, as further north near Gadag, are faulted against the granite gneiss, the downthrow being on the west side of the fault. The fault crosses the Tungabhadra and runs on for some 4 miles, when it is crossed or joined by another fault, running nearly east-north-east to west-south-west, and is no longer traceable to the southward.

The Tungabhadra gorge section.

To the west of Dambal town the band of Dharwar rocks is fully 13 miles wide, but it narrows greatly as it approaches the Tungabhadra, being a little less than 5 miles across in the gorge of the river. The section here seen shows, when followed from east to west, the following series :—

10 Hornblendic schists.
9 Hornblendic trappoid.
8 Contemporaneous trap.
7 Trappoid.
6 Flaggy hæmatitic quartzite.
5 Boulder conglomerate.
4 Contemporaneous trap.
3 Schists and argillites.
2 Hæmatitic schists.
1 Hornblendic Trappoid.

Of these the conglomerate is the most noteworthy because of its extreme coarseness, many of the boulders included being more than 1½ foot in diameter. The conglomerate is very little altered, apparently, and boulders which have weathered out are perfectly smooth and water-worn. None were seen showing any striations on groovings.

Continuance of the band into Mysore.

The hornblendic schists seen at the eastern end of the gorge section extend southward, and appear to form the backbone of the high ridge forming the bold Bettada Mallapan Gudda. The extension of the beds forming this ridge may be clearly traced by the eye for a long distance south-east. The ridge sinks down as it approaches the valley of the Chinna Haggari, south-east of which detached hills of schistose rock indicate the continuance of the Dharwar band up to and across the Mysore frontier. Another ridge of hills rises here and connects the Dharwars of Harpanhalli taluq with those around Jagulur.

Honnamaradi gold-field.

A few miles south of Jagulur occurs another auriferous tract that yielded highly promising quantities of gold on washing the sands of two streams rising on the west and east sides respectively of the little hill lying north of Honnamaradi. The hill consists of

drab or yellowish gritty schist passing into argillite in parts, on the south-western side of which several medium sized reefs of quartz appear running nearly north and south. Immediately east of the Honnamaradi (golden hill), the gneissic rocks are seen with an apparently faulted boundary in between. On the bank of a small nullah which flows south, a couple of hundred yards to the east of the hills are the remains of some large dumps where the old jalagars had evidently washed the sands for a considerable time. A washing of "dirt" from the bed of the nullah gave a handsome show of gold, of good grain and excellent colour; while a washing from the little rivulet flowing from the western side yielded a rich show of very coarse gold of the highest quality.

No gold was seen *in situ*, but there is every reason to believe it came from the reefs above referred to, as the streams in which the washings were made, especially the western one, have such very short courses that they could not have brought their gold-supply from any great distance. West of the schist beds forming the Honnamaradi hill and the tract westward of it, appears an underlying bed of jaspideous quartzite which has been tremendously brecciated by some obscure cause. The rock weathers of a very dirty dark colour, nearly black in many places, and is often very obscure in character and hard to determine. The breccia character becomes obvious only when the enclosed jaspideous pieces are paler than the matrix.

The Goeshwar hill trap flow.

West of, and underlying the brecciated quartzite is a great development of contemporaneous black trap (diorite ?) which extends southward a long way and forms great part of the mass of the fine Goeshwar hill, the loftiest hill in the band northward of Chitaldrug.

Kotemaradi gold-field.

Proceeding southward still, we come to the Kotemaradi auriferous tract, which consists of a great bed of chloritic schists overlaid by quartzites, and these again by a thick series of other schists, the lower beds being argillites. Traces of a contemporaneous trap show along the western basement of the Dharwars.

Quartz reefs are rare or else covered up by the extensive talus. The only one of any size seen was a good-looking one of bluish quartz running through chloritic schist at foot of the western slope of the southernmost of the three big hills which rise northward of the little Kotemaradi hill. The reef is just north of the stream draining the western slopes and close to some old workings of small extent.

Quartzites a possible source of gold.

The quartzites on the Kotemaradi are of no great thickness, and are locally much altered, nearly converted in many parts into true quartz, and generally permeated by large numbers of small quartz veins. It will be curious to ascertain, as doubtless there will ere long be opportunities of doing, whether this altered quartzite contains any gold. It is certain that the small stream draining the western and northern slope of the Kotemaradi carries down a notable quantity of large gold of excellent colour, and that no reefs of any size or importance show through the extensive talus covering the slopes.

Chital drug granite hill.

To the south of Kotemaradi, the Dharwars form a small bay opening to the west, at the southern side of which stands the old town

of Chitaldrug, with its grand old granite hill capped and surrounded by a noble fort or Drug, formerly one of the centres of the Bidars, one of the bravest and most independent of the Hindu tribes in the Deccan.

Jogamaradi trap flow.

Belligudda copper mines.

To the south of Chitaldrug the basement bed of the Dharwars is a great contemporaneous trap of great thickness and extent which forms the summit of the Jogamaradi, one of the highest mountains in this part of Mysore. Overlying this great trap formation is a great thickness of schists, some of which form the Belligudda (hill) noteworthy as having contained some considerable pockets of copper ore, which were exhausted by miners of whom no record appears to exist. The ore mined was, as far as can be judged from the refuse heaps, an earthy malachite, or carbonate of copper. No signs of a lode can be seen running through the clay-schist forming the Belligudda, The axis of the hill is a hard bed of jaspideous hæmatite quartzite which stands nearly vertical.

Halekalgudda side band.

To the south of the Jogamaradi mountain, south of Chitaldrug, the width of the great band is nearly doubled by the junction with it of a parallel band, which commencing somewhere to the south of Harpanhalli[1] forms the Halekalgudda and some other hills east of Maya Konda, and then sweeps into the main band. A little to the east of the junction, the Dharwar beds attain their greatest elevation in this part in a peak to which the Trigonometrical surveyors assign a height of 3,863′ above sea-level.

The geological structure of this side band, which may conveniently be called the Halekalgudda band, shows no special features so far as it was examined, unless it be a rather greater development than usual of gritty, locally conglomeratic quartzites. With these are associated siliceous, micaceous and chloritic schists. These are underlaid by a great flow of dioritic trap which in its turn is underlaid by a considerable thickness of schists. Some fine quartz reefs cross the footpath crossing the hill south-westward from Halekalgudda village, but none were seen near it, though a good show of gold was obtained by washing near the north end of the hills. Where the highroad from Chitaldrug to Holal Kere crosses the southern part of the Halekalgudda band the country is very flat and much obscured by thick red soil, but the connection of this band with the main one is made clear by the existence of a low ridge formed by an outcrop of a purely ferruginous bed of hæmatitic quartzite which rises rapidly, both to the north-west and south-east, and soon becomes an important object in the landscape.

The fine views to the south obtained from the tops of Belligudda and Jogamaradi show the Dharwar rocks extending far to the southward in great force towards the great gorge by which the Haggari river (locally known as the Varada) cuts through the hills of the Dambal-Chiknayakanhalli band, while from the south from the highest point east of Chiknayakanhalli town the beds are seen to range continuously northward to the same point. Though not traversed as yet by the geological surveyors, there is ample evidence as to the existence of the Dharwar rocks between the known tracts near Chitaldrug and Chiknayakanalli.

[1] The northern extremity of this side band has not yet been visited, so its exact position is not known. It extends about 50 miles in length.

The Chiknayakanhalli gold field.

At Chiknayakanhalli we come again upon an auriferous tract which is frequently spoken of as the Chiknayakanhalli gold-field. On Honnebagi hill, a couple of miles south-east of the town, old workings of no great size occur just within the boundary of the Dharwar area. The reefs occurring here are not promising in superficial appearance, being white and hungry-looking; but the quantity of gold obtained by washing in the small streams flowing down the hill is not by any means contemptible, and deeper prospecting might give still more favourable indications.

Dodrampur hill synclinal.

The basement bed is here a quartzite which is overlaid by a thick series of schists, hornblendic, chloritic and micaceous, occupying the space up to the foot of the hills, where they are overlaid by argillites and a great thickness of hæmatitic schists, locally very rich in iron. The weathering of the highly hæmatitic schists gives rise to the formation of subaerial breccias which assume a lateritoid appearance from the action of percolating rain water. The denudation of these rich, red argillites and hæmatites gives rise to the formation, further to the south, of an extensive talus of deep red soil.

The stratigraphical position of the main ridge east of Chiknayakanhalli appears to be an elevated synclinal, but the eastern side shows a succession of formations discordant from that on the west, and there may very probably be a fault running parallel with, but a little east of the axis of the synclinal.

Dodrampur limestones.

About half-way down the eastern flank are extensive and important formations of sub-crystalline limestone, mostly grey in colour, and with very numerous siliceous partings in the form of quartzite, which here and there attain to the magnitude of distinct beds. These limestones must be several hundred feet thick. East of the little fortified temple of Dodrampur they are underlaid by a great chloritic schist formation. The limestones cover a large area stretching away south-east from the main ridge, and a small show of them is to be seen on the west side of the main ridge, just opposite the mouth of the deep gorge east of Ballenhalli.

Kibbanhalli branch band.

To the south-west of Chiknayakanhalli lies a branch of the band which runs north-west some 14 or 15 miles from its point of divergence from the main band. Where crossed by the high road from Shimoga to Bangalore, it is seen to have a great flow of trap as its base, on which rest chloritic and other schists to a considerable thickness. To the south of the point of divergence just referred to, the whole band trends strongly eastward, and keeps on the left bank of the upper course of the Shimsha river. I was unable to follow it up east of the Shimsha, but I feel convinced that the Dharwars stretch away south-west by Kunigal, and then south, past Huliyurdroog and further south, narrowing greatly the while, across the Madras railway. The hills stretching away south of the Yadiyur-Kunigal road present the dark colour and smooth appearance so characteristic of the Dharwar rocks elsewhere, while the country round Huliyurdroog is well known to be auriferous, and the look of it from the railway near Mudgeri station on the Mysore State Railway assures me that it is so.

Kunigal-Huliyurdroog extension of the main band.

On theoretical grounds I believe that a great band of Dharwars, by its geographical position an extension of the Dambal-Chiknayakanhalli-band, stretches south from the valley of the Cauvery, near the falls of Siva Samudram, across the Kollegal taluq, and down near to the valley of the Bhowani river, if not yet further south into the central part of Coimbatur District. That a second parallel band of the same rocks may exist further east near Kandali, I regard as more than probable. It will assuredly contain the extensive old workings known to exist in that immediate neighbourhood. I do not mark these bands in my map, as I have not been able to obtain sufficiently close views of them to lay down their actual positions.

Extension southward into Coimbatur District.

The Kollegal bands.

To return to the Dambal-Chiknayakanhalli band, at its eastern bend in the upper valley of the Shimsha river; the main band, as far as width is concerned, appears to be the Kunigal band. The branch which diverges from it a few miles north of the Yadyur bridge over the Shimsha is a very narrow one to start with, but widens a little near Nagamangula only to contract again and remain a narrow tract, as far as traced, down southward of the Cauvery immediately east of the east end of Seringapatam island. I will designate this as the Shettihalli band.

The Shettihalli branch band.

A little south of the Yadyur bridge an auriferous tract is encountered close to the village of Kalinganahalli. Here good washings of gold are reported by Mr. Chas. Ogden, M. E., but no reefs of any size could be seen, merely small veins in great numbers traversing the country rock. Numerous dumps thickly scattered about show that the old miners had been busy here washing on a large scale.

Kalinganahalli gold washings.

The Dharwar rocks seen here are hæmatitic quartzites of no great thickness, but very distinctly marked, with overlying chloritic and hornblendic schists, which stretch down south till abreast of Nagamangala. Various good-looking quartz reefs occur in this tract.

A mile and half south by west of Nagamangala town is Honnabetta hill, an outlier of the Dharwars, consisting, so far as examined, of hornblendic and chloritic schists, with at least one fine-looking reef at the northern end of the main hill. A good washing was obtained in the stream draining the north-east side of the hill. A mine is being opened at the extreme north end of the Honnabetta outlier on a reef running through chloritic schists, which is traversed closely by a pale green dioritic (?) trap. This is the Girigudda mine. I obtained a very fair result by washing in the little stream draining the east side of Girigudda hill. Chloritic schists form the mass of the small, but rather high spur which diverges from the Shettihalli band and crosses the Lokapavani river some 10 miles S. S. W. of Nagamangala.

Honnabetta outlier.

Girigudda mine.

Further south, where the Mysore State Railway crosses the Shettihalli band, the Dharwars consist mainly of quartzites and horneblendic schists, and form a very unpromising region for mining, as far as surface indications go. The reefs seen are small, and the quartz is white and hungry-looking, and contains very few minerals. Those noted in it were blackish, greenish, mica, and a white decomposing felspar. The included minerals show but very rarely and at wide intervals, but here and there

become numerous and convert the reefs into true granite veins; rocks which are not as a rule rich in the precious metal.

Karigutta felspar porphyry.

The most southerly point to which the Shettihalli band has been examined is the Karigutta hill overlooking Seringapatam. The most striking feature here is a very fine large dyke of beautiful, reddish-brown felspathic porphyry, which might furnish an inexhaustible supply of a superb decorative stone fit for vases, panels, bases for busts, and tazzas.

The extension of the Shettihalli band southward of the Cauvery has not yet been followed up by me. But there can be no doubt that it does extend much further. I am not prepared, however, to support fully the idea which I fathered in the map accompanying my paper on the traverse across Mysore, that the Shettihalli band extended far to the south-west and joined the band of auriferous rocks forming the Wynaad gold-field, I have therefore indicated no such connection in the new map.

Notes on the Igneous rocks *of the districts of* Raipur and Balaghat, Central Provinces, *by* PRAMATHA NATH BOSE, B. Sc., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With a plate.)

The igneous rocks treated of in these notes occur in the jungle-clad border country forming the water-shed between the districts of Raipur and Balaghat, and situated north of Dongargarh, and west of Lohara, Gandai, and Khairagarh. They are, as a rule, unbedded; and they alternate with ridges of Chilpi shales and sandstones, which are probably of Transition age. Their general parallelism to the strike of the Chilpis is notable.[1]

Area; mode of occurrence.

Felsites.—These are almost exclusively confined to the eastern portion of the area, only a small patch having been encountered in the western portion, east of Bijagarh in the district of Balaghat. The ground occupied by the Felsites in the eastern area may be sub-divided into two portions—one lying to the north of Thakurtola, and the other to the south of that place. In both of these areas, they run north-south parallel to the strike of the sedimentary Chilpi strata; and in both, the eastern and western boundaries are approximately straight.

South of Doomureea (a village 3 miles west of Lohara), as well as near Koylaree (west of Silheti), the felsites were seen to be in lateral contact with highly altered vitrified quartzites. A mile north of Doomureea, on a felsite-hill locally known as Dalhea, I came across huge blocks of a hard, laminated, quartzitic-looking rock, which looked as if they had been carried up entangled in the felsitic mass. Small patches of shales and quartzites with the Chilpi strike, and belonging apparently to the Chilpi series frequently occur in the midst of the felsites, especially in the

[1] For a general geological map of a portion of the area, *vide* Rec. G. S. I., Vol. XVIII, p. 169.

country west of Doomureea. They look like remnants of beds which have been forced through by the felsites. One such patch was well seen just west of Magarkund. It is surrounded on all sides by the felsitic rocks.

The absence of bedding, the straightness in direction of the felsitic outcrops, the alteration visible in the adjacent rocks at places, and the presence of included Chilpi fragments, as well as of patches of Chilpi rocks in the form of islets, suggest the intrusive origin of the felsites.[1]

Age.

East and south of Thakurtola, as well as west of Khairagarh, the felsites are overlaid with a certain degree of unconformity by sandstones and conglomerates, which form the base of the Chhattisgarh Plain Series, and to which the name of "Chandarpur sandstone" has been applied. Chandarpurs lying in hollows, scooped out in the felsitic rocks is rather a common occurrence. We may hence infer, that the felsites are older than the Chandarpurs. The fact, that at places, as at Lumna (north of Thakurtola) and elsewhere, the basal conglomerates of the Chandarpur group contain rolled fragments of the felsites corroborates the inference. There are a few circumstances, however, which lead me to think, that the felsites cannot be much older than the Chandarpurs. It is even possible, that minor intrusions continued while the latter were being deposited. The vitrified quartzites west of Koylaree, and south of Doomureea, referred to above, have not been traced into indubitable Chilpis; and the occurrence of Chandarpurs in their neighbourhood raises the not unreasonable suspicion, that they may belong to that group. West and north-west of Thakurtola there are tuffs associated (to all appearance, interbedded) with the lower Chandarpurs; and these tuffs may have been formed of *ejecta* from felsitic dykes in the Chandarpur period. The felsites would thus appear to have been intruded through the Chilpis prior to, and possibly also, in part contemporaneously with, the deposition of the Chandarpurs.

Felsites intruded close to shore and parallel to coast line.

The small thickness and breccio-conglomeratic character of the Chandarpurs plainly declare them to be a shore deposit, and the Saletekri range (formed of Chilpi rocks) probably indicates the coast-line of the lake or inland sea in which they were deposited. The felsites would thus appear to have intruded as dykes close to shore, and parallel to the strike of the Chilpis, as well as to the ancient shore-line.

Petrography.

The typical form is a purplish rock much rent by fissures, and weathering to a brownish tint. The fracture is roughly conchoidal. Longish crystals of white felspar, and roundish ones of vitreous-looking quartz are macroscopically seen to be disseminated in it. The former are larger than the latter, some measuring as much as quarter of an inch in length. In the matrix, as well as in the crystals of felspar, a greenish decomposition product is often observed, sometimes to such an extent as to change the colour of the latter entirely to green.

[1] Intrusive felsites have been noted by Dr. King in the Kadapah formation (Chey-air beds), which is possibly of the same age as the Chilpis (Mem. VIII pp. 191, &c.). The remarkable parallelism of the felsites to the Chilpi outcrops, and the fact that they are seldom clearly seen to cross the strike, give them an appearance of being contemporaneous flows. But the presence of included fragments and of patches of Chilpi rocks is unfavourable to such a supposition.

Under the microscope, the groundmass is seen to be micro-felsitic. It is made up largely of minute slightly greenish, granules. Numbers of them are in some slides seen collected in interrupted, irregular, and more or less wavy lines. In a slice prepared from a specimen of a felsite which, though obtained from the southern portion of the district of Raipur, a little way to the south of the area under description, unquestionably belongs to the same series, as the felsites we are treating of, microlites looking very like those in question are seen to be aggregated along the outer boundaries of the quartz and felspar crystals, appearing, as if, in flowing past these, they had met with some obstruction, and in consequence stuck together (H, Fig 1, Plate). These bundles of microlites are somewhat elongated and strongly dichroic in polarised light. There can be hardly any doubt, that they are microlites of hornblende. And it is not improbable, that a portion of the minute greenish granules of the felsite under description also belong to that mineral.

The larger quartz crystals have invariably a more or less rounded shape, and the edges are not very clearly defined. Fluid inclusions are abundant. Protrusions of the groundmass (G. Fig. 2) in the form of bays, and also along narrow cracks are common. Isolated patches of the groundmass are found in some, though rarely; and a few contain cubical crystals of oxide of iron. The smaller crystals of quartz, unlike the larger ones just noticed, usually exhibit more perfect crystal surfaces.

The crystals of felspar are invariably impellucid, being full of granular matter. They are usually rounded off at the corners, some appearing nearly elliptical in section. Their outline, like that of quartz crystals, is, in some cases, very ill-defined. As in the case of quartz, inclusions and intrusions of the groundmass are not uncommon. The characteristic twinning of orthoclase is exhibited by some in polarised light. No plagioclase has been observed. Cleavage lines are sometimes well seen as in fig. 1.

Some of the appearances noted above in connection with the crystals of felspar and quartz would seem to suggest, that they have not crystallised *in situ*. The seemingly isolated patches of the groundmass found enclosed in some crystals may, in reality, be connected by cracks with the groundmass outside, the connection being cut off in section. The frequent indistinctness of the crystal boundaries may be accounted for by partial fusion along the edges.

The greenish alteration product, patches of which are, in some cases, macroscopically seen in the matrix, as well as in the crystals of felspar is noticed, under the microscope, to be slightly dichroic with polarised light. Even where the product in question has invaded the entire felspar crystal, so as to appear macroscopically a pseudomorph of the latter, it is found, under the microscope, to be quite patchy, the unaltered portions of the felspar exhibiting various bright colours under crossed nicols.

At Khairbana and generally along the eastern margin of the felsitic area, there occurs a non-porphyritic purplish felsite associated with tuffs at places. The rock is much fissured and has a very uneven fracture. It is eminently liable to alteration, being sometimes almost wholly converted into quartz-rocks, as near Gubra, and sometimes into pseudobreccias. No bedding, however, is noticeable anywhere; and here and there unaltered portions of the matrix are met with.

A thin slice of a specimen from near Khairbana has a blotched appearance,

small brownish spots and patches being interspersed in a light purple matrix. Under the microscope, a few small bits of rather pellucid felspar are noticed, which appear to be fragments of much shivered larger crystals. They are partially rounded off at the corners; and the brownish substance noticed above invades them to some extent.

It is doubtful if the rock is a genuine felsite. It is probably a tuff, at least in part, belonging to the felsite series.

A dark coloured felsite occurs at Murghusri, Mohanpura, &c. On a fresh fracture, the felspar crystals are barely recognisable with the naked eye. But, on the weathered surface, which is light brown, somewhat as in the porphyritic variety, they are conspicuous by their white colour. Owing to the similarity of appearance at the weathered surface, the variety under consideration could not be distinguished from the porphyritic variety noticed above, without devoting to the rocks more time than I could command. The former possibly belongs to an intrusion different from that of the latter. Certain it is, that the black felsite differs from the purplish porphyritic form, not in colour only, but also mineralogically, in the extreme rarity of free quartz in it, and chemically, in containing proportionately less silica. The percentage of silica, as ascertained by analysis in the survey laboratory, in the porphyritic quartz-felsite is 73·47, but in the felsite under notice only 68·57. This last proportion just exceeds the maximum limit of silica (66 per cent.) present in intermediate igneous rocks.

Under the microscope, the groundmass is seen to be microfelsitic, as in the porphyritic form. The larger crystals of orthoclase are full of minute granules (the result probably of kaolinisation), and have their corners more or less rounded off.

Basaltic rocks.—These occur in the Chilpi area north of Dongargarh and, like the felsites, run parallel to the strike of the Chilpis. They cover the entire ground about Ghoteea, Bunnara, &c., forming an ill-defined range of scraggy hills. On the north side they abut laterally against a high ridge of sandstones sloping gently with the dip north-westward. The junction on this side is fairly straight; throughout it, however, the sandstones were nowhere clearly observed to have undergone any special alteration. The eastern junction, east of Ghoteea, is similar to the northern. Along the southern junction, however, the sedimentary Chilpis were found to be distinctly and highly altered. North of Koolharghat, and just south of Lingungarh, as also south of Ghoteea, there were met with along the junction, dark, bedded, igneous-looking rocks, resting on Chilpi sandstones with perfect conformity. They contain more or less rounded grains of quartz in abundance, and at places, look like gritstones or even conglomerates, with a trappean base. South-east of Ghukooree, there occur at the junction peculiar looking schistose rocks. Both these classes of rocks appeared to me to be the result of contact metamorphism.

Area, mode of occurrence.

West and north-west of Luchna, the basaltic rocks occupy a very large area extending to north of Bukkurkutta, where they are covered by laterite. Patches of shales, and more rarely of sandstones, belonging evidently to the Chilpi series, and similar to those occurring among the felsites, were encountered in the basaltic area.

An alternation of basaltic rocks, which appeared like minor dykes, and quasi-schists was met with on the Kaman pass (one of the passes between the districts of Raipur and Balaghat).

North of Mahuadhar and just south-west of Nemao Tola, there is a ridge of the basaltic rocks, in which blocks and boulders of quartzites of all shapes and sizes, some measuring no less than 20 feet in length, were encountered.

At places, as just west of Sitapala, the Chilpi shales in contact with the igneous rocks were found to be altered into hard thick claystones. Elsewhere, as west of Kurela (Karol on map), a peculiar-looking schistose grit somewhat like the rock mentioned above as occurring south-east of Ghukooree, was met with as contact rock. Frequently, however, the shales and sandstones in contact were found to have undergone no special alteration.

Relative age.

The facts noted above with regard to the mode of occurrence of the basaltic rocks appear to indicate that they are of intrusive origin. The fact that they follow the strike of the Chilpis very closely may suggest, as in the case of the felsites, that they are contemporaneous flows. But, as in the case of the felsites, the presence of patches of Chilpi shales and sandstones in the midst of the basalts cannot on this view be satisfactorily accounted for. The mode of occurrence of the basaltic rocks in the vicinity of Ghoteea and Bunnara, however, gives rise to the suspicion, that they belong to a flow contemporaneous with the Chilpis. For the latter are remarkably altered south of Ghoteea, at the southern junction. But no such alteration was noticeable at the northern junction, *i.e.*, the junction with the higher beds of the series. This junction, however, was much covered by *debris* from the sandstone hills, and was, altogether very obscure. I would not, therefore, lay much stress on this negative fact, *viz.*, the absence of alteration; and the basaltic rocks of the neighbourhood of Ghoteea, like their fellows occurring further north, have in all probability, an intrusive origin; are, in fact, intrusive sheets. There is, however, considerable uncertainty about their age. There is a minor intrusion of them in the felsitic area at Magarkund, and another a little way south, at a place called Bagdoor. An intrusion of the rock was also met with north of Magarkund in the country west of Lohara about Katangi-Mohanpura. The manner in which these intrusions occur left the impression in my mind that they are more recent than the felsites and felsitic tuffs by which they are surrounded. I have got no data which would fix their age with greater precision. Unlike the felsites, they are nowhere superposed by the Chandarpur sandstones, or, indeed, by any other sedimentary rock, except by laterite on the Saletekri plateau.

Lithologically, the rocks under treatment differ in a very marked manner from the felsites, but resemble the Deccan and Malwa trap basalts, though not closely; and for all that was seen in the field, they might be of the same age as the latter.

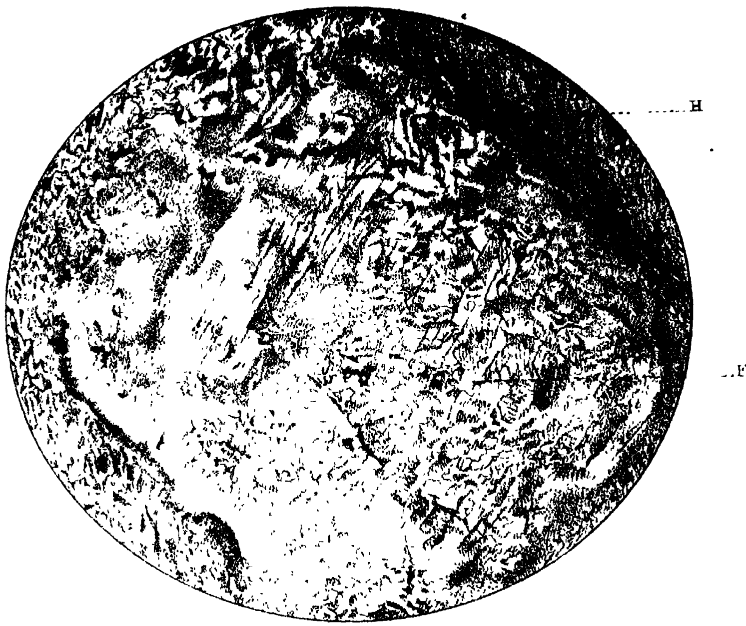
Percentage of silica.

By analysis of a specimen, in the laboratory of the Geological Survey, it has been ascertained, that the rock contains 49·57 per cent. of silica.

Petrography.

The basaltic rocks are hard, black, and compact. Macroscopically, black rod-like, minute crystals are visible in some. Under the microscope, these crystals are seen to be of a greenesh tint, slightly

Fig 1



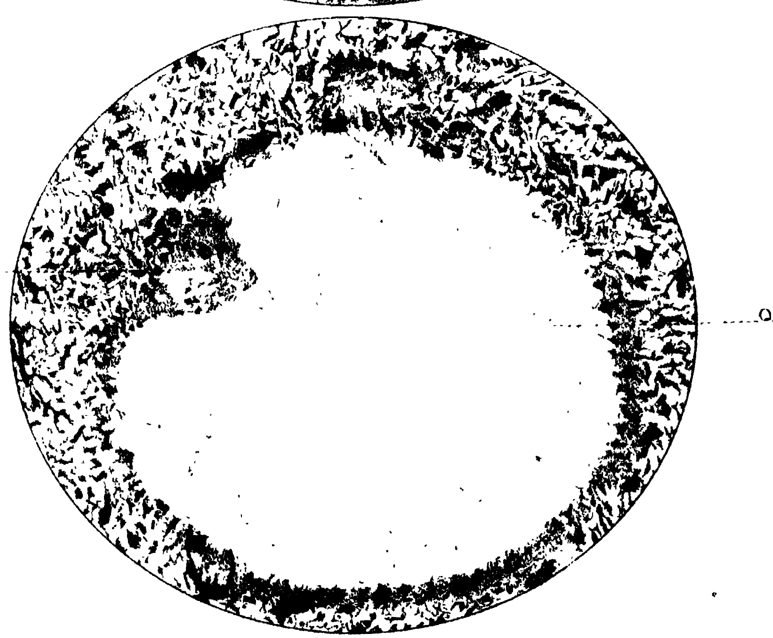


Fig 2

but distinctly dichroic. They are as a rule irregular shaped; but a few eight-sided sections have been noticed. The mineral is, in all likelihood, augite. The groundmass is crypto- to micro-crystalline. Minute, rod-like, whitish crystallites, probably of felspar, are present, as also greenish microlites. Large felspar is rare; when present it is ill developed, and barely distinguishable as plagioclastic. Magnetite occurs, but not in such abundance as in the Deccan and Malwa trap basalts.

In mineral and chemical composition, the rock presents close analogy with basalts.

Tuffs, volcanic agglomerates.—The association of tuffs with the Lower Chandarpurs west of Thakurtola has been already alluded to.[1] The most characteristic variety is a gritstone-like rock, very hard and massive-bedded, and weathering in huge, roughly spheroidal masses. Their matrix varies in colour from nearly black to very light pink, presenting various intermediate tints. The black forms are the most volcanic-looking, and the light the most sedimentary-looking. In fact, the last named varieties pass almost insensibly into ordinary whitish gritstones, as at Manpur and Lumna. Macroscopically, the gritstone is seen to contain large quantities of felspar and quartz in about equal proportion. The felspar varies in colour from white to flesh-coloured, and is, in the average, of about the same size as the orthoclase of the felsites. The quartz, however, is much larger than that of the last-named rocks.

Under the microscope, the matrix, which appears nearly homogeneous to the unassisted eye, is seen to be full of little bits of felspar and quartz. There is some interstitial matter, which is somewhat like the groundmass of the felsites. The felspar is found to be of the same species as in the felsites; some of the crystals bear evidence of abrasion at the edges. The quartz crystals have a most irregular outline, and like the felspar, have undergone some amount of attrition.

That the gritstone-like tuffs are water-laid, there can be hardly any doubt. They are, in all likelihood, formed partly of volcanic ejecta, and partly of sedimentary material.

The possibility of the non-porphyritic purplish felsites in the neighbourhood of Khairbana being, at least partly tuffs has already been adverted to. The fine-grained tuffs vary considerably in colour from purplish to black. Some are smooth and homogeneous with conchoidal fracture; others rough, with rather coarse and uneven fracture. The tuffs not unoften pass almost imperceptibly into well recognisable, clearly bedded sedimentary strata, as north-west of Bagdoor, north of the road leading from Gandai to Thakurtola.

EXPLANATION OF PLATE.

Figs. 1 and 2. Porphyritic Quartz-Felsite, south of Khuji, Raipur district.
,, F. felspar.
,, Q. quartz.
,, H. bundles of horneblende microlites.
,, G. Groundmass.

[1] *Vide* page 56.

Report on the Sangar Marg *and* Mehowgala Coal-fields, Kashmir, *by* TOM D. LATOUCHE, B.A., *Geological Survey of India.* (With one plate.)

Two areas in which coal-bearing rocks (which, for the purposes of this report, may be called "coal measures," though this term must not be taken to imply any connection with the true coal measures of Europe) are found, were examined by me,—the one occurring on the western and northern flanks of Sangar Marg hill, and the other in the valley of the Neari Tawi river, a tributary of the Bari Tawi, about 8 miles to the west of Kotla, surrounding the village of Mehowgala. These may be called the Sangar Marg and Mehowgala coal-fields respectively, and I shall describe them separately. The coal measures are probably continuous between these two areas, though separated at the surface by a broad band of newer rocks; but in most places are at too great a depth to be reached by mining. I spent only a few days in the examination of the Mehowgala field; but as the rocks met with are practically the same as those at Sangar Marg, and as they are much less disturbed by folding, I was able to form an opinion on their extent and condition more rapidly than in the case of the latter field.

I.—THE SANGAR MARG FIELD.

Geology.—The following is a vertical section of the rocks exposed in the field, such as would be found in a boring or well, sunk vertically through the strata where horizontal. It should be remembered that where the strata are inclined, as they almost invariably are in this field, the thickness of each bed passed through by a vertical boring would be greater than that here shown, in proportion to the angle of dip; also, the thickness of the different beds may not be exactly the same over the whole area, though that of the whole group appears to be very constant. For instance, I found the thickness of the band of carbonaceous shale immediately overlying the coal seam to vary from 3 to 10 feet within a short distance, and the thickness of the seam itself is also variable. The amount of overlying Murree Sandstone passed through would, of course, depend on the position of the boring if commenced in that rock. Its total thickness is unknown, but must be several thousand feet. That of the Great Limestone, too, at the base of the series is unknown, its base being nowhere exposed:—

Formation.		Description.	Thickness, feet.
Murree Group . .		Grey and reddish-grey sandstones, with beds of shale, weathering purplish-red . . .	Undetermined.
Subathu Group (coal measures) . .		Nummulitic limestone, upper band, hard blue limestone, with large nummulites . .	
	Upper shales.	Olive shales, with occasional thin nodular calcareous bands, sometimes containing small nummulites passing down into .	200
		Finely laminated olive shales . . .	
		Nummulitic limestone, lower band . . .	

Formation.		Description.	Thickness, feet.
Subathu Group (coal measures)—*contd.*		Earthy limestone, crowded with small nummulites	20
	Middle Shales.	Shales, sandy near top, passing down into carbonaceous shales at base	125
		Thin band hard sandstone, with pyrites	3
		Carbonaceous shales	3 to 10
		Coal	2 to 5
	Lower Shales.	Finely laminated olive shales, carbonaceous near top	70
		Indurated pisolitic clay	5
		Brecciated conglomerate with iron ore	Variable.
Supra Kuling Series.		Great limestone	Unknown.

It will be seen that the greater part of the coal measures consists of shales, with a few subordinate beds of harder rock, and that the coal seam occurs in the lower part of the formation, the shales on either side of it being carbonaceous. There is in this field only this one seam of coal, which is always found at or about the same horizon in the shales; the lower band of nummulitic limestone is a very useful guide to the position of the seam in any outcrop of the coal measures; as, being a hard rock, it weathers out more or less conspicuously from the surrounding shales, and the coal will always be found, if at all, at a certain distance beneath it.

In order to describe the distribution of these rocks in the coal-field, it will be convenient to take the lowest formation exposed, *viz.*, the *great limestone* (so named by Mr. Medlicott), as the higher rocks are everywhere conformable to the folds into which it has been thrown, except where the boundary between them is a faulted one.

This rock forms the main mass of Sangar Marg hill, where it is thrown into the form of a broad anticlinal curve or arch, with its axis running approximately east and west. This anticlinal is flanked on either side by two synclinal curves or troughs, occupying the valleys near the head of which the villages of Bugoola and Sujanpur are respectively situated. I shall accordingly speak of them as the Bugoola and Sujanpur synclinals. On either side of these again, the *great limestone* is bent up in narrow anticlinal folds, forming, on the south, the precipitous ridge to the north of Berh, and on the north a similar ridge along the northern side of the Sujanpur valley. In its easterly continuation along the line of the Puddar valley, this fold is faulted parallel to its axis.

The axes of all these curves are elevated towards the east, so that the anticlinals disappear gradually in a westerly direction. At the same time the synclinals between them broaden out. Thus the narrow ridge of *great limestone*, north of Berh, disappears near the village of Kroli on the path from Berh to Kotla; the *great limestone* forming the main or Sangar Marg anticlinal, disappears about 1½ miles west of the tank at Chakur; and that forming the ridge north of Sujanpur, near the lower end of the Sujanpur valley. Similarly, the depressions caused by the synclinals grow shallower, and tend to disappear in an easterly direction.

To the south of this system of folds, the rocks are much disturbed and faulted, and even inverted in places, so that the *Murree sandstones* are sometimes in contact with the *great limestone*, or appear to dip beneath it, as may be seen along the path leading from Berh near the village of Kroli; while the coal measures are either faulted out of sight, or so broken up as to be valueless. To the north, *Murree sandstones* apparently extend to the foot of the Punjab range.

Owing to the combined effect of the folds into which the rocks have been thrown, and the denudation to which they have been subjected, the coal measures appear at the surface as a continuous narrow band, running in an irregular direction between the *great limestone* and *Murree sandstones*. The area occupied by the *Murree sandstones* may be readily distinguished from that of the *great limestone* by the purplish-red colour of the soil formed by the weathering of the former, and the more rugged character of the hills formed by the latter.

Distribution of the Coal measures.—It is difficult to convey an accurate idea of the distribution of the coal measures without a large scale map; but I have prepared a section taken across the western portion of the field in a direction transverse to the strike of the rocks, which will be of some assistance in distinguishing the various folds I have described above. The section is attached to this report.

a. The Bugoola synclinal.

Entering the Kotla valley by the path from Berh, coal is first met with on the top of the low pass or *col* near the village of Kroli (or Krool, which is somewhat to the east of its position as marked on the map).

The seam where first seen is a good deal disturbed, but seems to be from 4 to 5 feet thick; a short distance to the west, however, it is reduced to 2 feet 9 inches. The dip is apparently towards the *great limestone*, but within a few feet to the south, the dip of the overlying rocks is about 67° to S. W., or away from the *great limestone*. To the south-east of this point, the coal measures occupy a small valley at the foot of the *great limestone* ridge north of Berh, and are cut off to the south by a fault.

On the descent from the pass above mentioned to the Kotla valley, the coal measures follow the path for about ¼ mile to a patch of terraced fields; here they bend sharply to the east round the western end of the narrow ridge of *great limestone*, and enter the Bugoola valley. Along the southern side of the valley, they are deeply eroded, and generally concealed by cultivation and debris from the limestone ridges, but coal is exposed in more than one place; the dip is high to north. Near the upper end of the valley, at the place called Kala Mitti by the natives, the band of coal measures bends again sharply to the west along the northern slope of the valley. At the bend, denudation of the shales containing the seam has exposed it in such a manner as to make it appear that there is more coal here than else-

where; hence the distinctive name given to this spot. That there is, however, a considerable thickness of coal here, I found by a cut made across the beds where they were not denuded, and by a pit sunk some 300 yards to the west, along the southern outcrop. In the former place, the seam was 3 feet 6 inches thick, and in the pit 7 feet 6 inches. This pit afforded a striking instance of the manner in which the seam may be concealed by surface soil. At the surface, only a few inches of coal were visible, and that only where the grass had been worn away by a footpath, and yet not 10 feet below there was this thick seam of coal.

Along the northern side of the valley, the coal meaures, dipping steeply to the south, are again eroded as far as the village of Kori, where a ridge of *Murree sandstone*, jutting out from the southern flank of Sangar Marg hill, has escaped denudation and protected them. Coal is again exposed on the *col* at the top of this ridge, between Kori and Ransu on the left bank of the Tawi, and again to the west at the lower end of the ravine near Ransu, just above the fields belonging to the village. On the *col*, the seam is 4 or 5 feet thick, and in the ravine about 3 feet.

The centre of the valley is everywhere occupied by rocks higher in the series than the coal seam; that is, by the upper beds of the coal measures towards the head of the valley, and by *Murree sandstones* lower down; so that the coal might be reached either by vertical mines on the floor of the valley, or by horizontal adits driven at points low down on its sides. In the middle of the valley, however, these upper rocks are nearly vertical, and it is impossible to say at what depth the coal seam would be reached. This could only be determined by boring. I do not think that for a mile at least down the valley from Kala Mitti, this depth would be found too great for mining on English methods; though in the lower portion of the valley a considerable water discharge would have to be contended with. Working from the outcrop should in no case be permitted in such highly inclined seams, as such openings would greatly facilitate the passage of water into the seam.

On the banks of the Tawi stream, near Ransu, the coal measures are entirely concealed by cultivation; and, where they cross the river, by its deposits of gravel and boulders. To the west of the stream they appear again in the ravine along which runs the path to Chakar, and coal is exposed on the path itself in more than one place as far as the *col* where the path from Brehal to Chakar is met. On the *col*, the coal seam is 2 feet 6 inches thick, dipping to S. 15° W. at about 20.° Down the ravine towards Brehal, the thickness of the seam increases, but at the same time the dip becomes much higher, until at Brehal it is nearly vertical. Here the seam is from 4 to 5 feet thick, but the shales in which it occurs are much contorted on a small scale, and the coal is crushed to powder. To the south, however, the dip of the rocks overlying the coal decreases, though still very high, about 70° in a southerly direction; and the coal would probably be found improved in condition if reached by a mine; but even at a short distance from the outcrop, it would be at a great depth owing to the high dip. Further to the west of Brehal, the seam again grows thinner. It is last seen in a small stream about ½ mile to the west of the Brehal outcrops, and is only 2 feet 2 inches thick, but with a lower dip, 37° to S. 20° W.

To the south of Brehal the dip of the rocks overlying the coal, as may be seen from the accompanying section, is very high, as far as the Tawi, and in the level ground near the river, the coal seam must be at a great depth beneath the surface;

but it might be worth-while to make a boring to the south of the river near the village of Kahiar, which is almost in a line with the sharp anticlinal ridge of *great limestone* at Kroli, and where the coal measures may be brought up within a reasonable distance of the surface.

b. The Sujanpur synclinal.

Ascending the hill side to the north of Brehal over *great limestone* and breccias, coal is next found about ½ mile to the west of the tank at Chakar, at the base of a scarp formed of coal measure rocks overlaid by *Murree sandstones*. When first seen, the seam is only 1 foot thick, and appears to die out entirely to the west where the coal measures bend down towards Brehal over the top of the main anticlinal (*vide* section).

To the east, the seam increases gradually in thickness as far as a point about 100 yards north of the tank, where it is from 4 to 5 feet thick. Here the coal measures bend to the north along the gully leading to the head of the Sujanpur valley, the thickness of the seam again decreasing until it is only 1 foot 4 inches at a point about 800 yards north of the tank. Beyond this, it disappears as a seam, and is represented at intervals by highly carbonaceous shales with lenticular beds or pockets of coal as at the top of the *col* above Sujanpur, and again about half way down the valley on the north side. Towards the lower end of the valley no coal is seen, but the coal measures are much concealed by talus from the steep ridge of limestone to the north.

At the village of Saroda-bar, on the top of Sangar Marg hill, is a small outlying patch of coal measure rocks which occupies the head of the Sujanpur synclinal, and has hitherto escaped denudation. The outlier is of no great extent, and its position at the top of the hill probably renders it worthless for mining purposes, just as at Kala Mitti, the amount of coal exposed by the denudation of the seam is apparently large, but this appearance is rather deceptive.

c. The Ikni and Paddar outcrop.

At the lower end of the Sujanpur valley, the band of coal measures makes another sharp bend round the western end of the narrow ridge of *great limestone* to the north, and runs due east in the direction of Ikni. It is probable that a fault exists along this line which has dropped the lower part of the coal measures out of sight in places; but even where fully exposed, until the ravine close to Ikni is reached, no coal is seen in them. The dip all along this line is very high, about 60° to the north, and the *Murree sandstones* overlying the coal measures rise into lofty hills directly from the outcrop, so that mines could not be sunk to the north of it so as to reach the coal except at a very great depth; though adits might be driven horizontally in a few places to the south of the outcrop so as to undercut the seam. The thickness of the seam at Ikni is variable, but reaches as much as 8 feet in places.

To the east of Ikni, the coal measures are continued along the same line down the Paddar valley, but are occasionally cut out by the fault, which gradually increases in throw, the *great limestone* to the south of it forming a lofty scarp along the southern side of the valley. Coal is seen about half way between Ikni and Paddar, very shaly and nearly vertical; and again at Paddar village[1] itself, where a few pockets

[1] This village is not in the position marked on the map, but is about 3 miles due E. of Lena station.

occur in vertical shales. Below Paddar, the coal measures are eroded and concealed by talus, but may be traced as far as the Rad stream which joins the Chenab at Arnas. Crossing the Rad stream, they enter the hilly country to the north of it, dipping steeply to the north between *great limestone* on the south and *Muree sandstone* on the north, but appear again on the same line at the junction of the Aus and Chenab, and may be traced for some distance up the valley of the latter river to the east. The coal measures, as a whole, seem to be much thinner here, but the different limestones and shales are all represented, and near the village of Kantan, about $1\frac{1}{2}$ miles east of Arnas, I found a small pocket of coal in them. Beyond Kantan, they again enter the hilly ground to the north of the Chenab, and I did not trace them further; but in this direction the coal appears to be confined to small pockets in the shales.

Condition of the Coal.

In all places where the coal is exposed at the surface, it is found to be in a very friable and flaky condition, crumbling easily between the fingers. This is partly due to weathering, and partly to the crushing the rock has undergone during the folding of the rocks. In order to find out whether the coal improves in the interior of the seam, I had a pit sunk near the tank at Chakar so as to reach the coal where it had been unaffected by weathering: the pit was 120 feet from the outcrop in one direction, and 190 feet in another, and coal was reached at about 30 feet from the surface. The rocks passed through were the following:—

	Feet.
Surface soil about	3
Shales, becoming gradually carbonaceous towards the base, about	13
Hard carbonaceous sandstone, with many nests of iron pyrites, about	4
Highly carbonaceous shales, with pyrites, about	10
Coal	Not passed through.

A good deal of water was met with in passing through the sandstone bed; and as the sappers and miners employed in sinking had no proper appliances for lifting the water, the sinking was a very slow process, and I stopped it as soon as coal was reached. The coal extracted is in a very different condition from that at the outcrop, being hard and compact, and not liable to be broken up by carriage to a distance. It is dull black in colour, with thin veins of brighter coal, and burns without flame in an open fire. The laboratory assay is:—

Moisture	·55
Volatiles, exclusive of moisture	11·48
Fixed Carbon	45·50
Ash	42·47
	100·00

Cakes, but not strongly. Ash, grey.

Pits were also driven into the seam, at Brehal and Ikni, to a depth of 20 feet from the surface, where they were stopped by water collecting in them. In these the quality of the coal showed no improvement, but they were not driven far enough to decide the question. The rocks at these places are more highly inclined and crushed than at Chakar, so that it is not likely that the coal would improve within so

short a distance from the outcrop as at that place. In the Bugoola valley,[1] the crushing was probably not so great; and here the coal in the interior of the seam would probably be found similar to that from Chakar.

II.—THE MEHOWGALA FIELD.

Distribution of the coal measures.—In the valley of the Neari Tawi, a small stream running due south about 8 miles to the west of Sangar Marg, between the villages of Acker and Mehowgala, the *great limestone* is again brought up to the surface on the line of the sharp anticlinal north of Sujanpur, forming a dome-shaped mass in the centre of the valley, through which the Neari Tawi passes in a deep narrow gorge. The coal measures, with the overlying *Murree sandstone*, are exposed on all sides of this central mass, dipping away from it in every direction. The dip of the rocks is, as a rule, much less than in the Sangar Marg field; and if the coal seam were fairly constant in thickness, it could be worked under much more favourable conditions than in that area. Wherever the seam is exposed, however, it is found to be very irregular, sometimes thickening out within 30 or 40 feet, from 2 to 5 feet, and thinning as abruptly. At the same time, such lenticular beds of coal seem to be fairly numerous, and no doubt in the aggregate contain a large amount of coal.

The rocks forming the coal measures are of about the same total thickness as in the Sangar Marg field, as shown in the vertical section at the beginning of this report, but there are some changes in the minor beds. Thus the breccias at the base are absent, and the pisolitic clays overlying them are replaced by a hardened clay rock which is locally carbonaceous, and contains thin strings and lenticular beds of coal. These are well exposed at the village of Mehowgala itself, and on the paths leading down from it to the Neari Tawi. There are also two seams of coal about the horizon of the seam in the Sangar Marg area, with a thickness of about 20 feet of shale between them, but the upper seam is apparently never more than 2 feet thick and is generally less.

To the west of Mehowgala, the strata are so horizontal that the stream in the iro valley has cut down through the overlying *Murree sandstone*, and exposed the coal measures. The valley is a broad open one, and the upper portion of the coal measures occupy the greater part of its floor, but the horizon of the coal seams has been reached only near the head of the valley. Here the lower seam has a fairly

[1] NOTE.—Specimen from a pit near Bugoola gives:—

Moisture	·17
Volatiles, exclusive of moisture	8·67
Fixed Carbon	39·13
Ash	52·03

Cakes. Ash, light reddish-grey.

This and the above assay must be considered as very disappointing owing to the large quantity of ash: and if they could be relied on as indicating the average quality of the coal would be in themselves a death-blow to the hope of getting a serviceable fuel from this area. Such analyses, however, being made on a very small portion of the coal are apt to be misleading; and before condemning the whole seam, I would recommend that a sufficient quantity of coal for trial in a steam engine should be raised from the 10-foot pit at Bugoola, and sent down for experiment on the Jummu railway construction.

constant thickness of about 2 feet, with many lenticular beds of a greater thickness. One of these that I measured was about 60 feet long thickening from 2 feet at either end to 5 feet in the centre.

In the Neari Tawi valley, coal is exposed on the path leading from Acker down to the river, but here also it occurs in lenticular beds. In the bed of the river, the coal measures are concealed by gravels and boulder drift. In the vicinity of the central mass of limestone, both on the north and south, there is some local faulting, and the strata are a good deal disturbed; but further up and down stream, the dip settles down more regularly to the north and south respectively. Borings might be made, say, ½ mile from either end of the narrow gorge, to find the depth of the seam.

Condition of the Coal.—At the outcrop the coal is in the same flaky and friable condition as at Sangar Marg, but as the rocks have undergone very little folding, it no doubt improves in the interior of the seam.

The Golan Stream.—Between the Sangar Marg and Mehowgala fields, the coal measures are brought to the surface in the narrow valley of the Golan stream about a mile above the place where the path from Kotla to Mehowgala crosses it. The horizon of the coal seam is not exposed, the lowest rock seam being the lower band of nummulitic limestone, which forms a dome-like ridge on the right (W.) bank of the stream, but a boring of no great depth would reach the coal if present. The rocks, however, are much folded, and the coal could not be worked to any great distance.

GENERAL REMARKS.

It would be very difficult to give a satisfactory estimate of the total quantity of coal available in these fields, at any rate until the thickness of the seam has been thoroughly tested by boring; and I shall not attempt to do so. My opinion is that there is a large amount of coal, but spread over so large an area that the average thickness of the seam is not great. Whether it would be profitable to work a seam only 2 or 3 feet in average thickness, must depend on the demand for coal in the Punjab, and the distance of the nearest railway line. A large initial outlay would have to be incurred in any case in making borings and sinking pits on a European system before any coal could be extracted, as it would be very unadvisable to work the coal from the outcrops, as might be done if the strata were more horizontal.

As it is impossible to mark the sites I have selected for borings in so small a map as the 2 miles = 1 inch which is the largest at present available, I append a table giving a list of the different places in which borings might be made, with the rocks exposed at the surface in which the borings would be commenced, and the dip of the rocks. Most of these I marked in the field with a small cairn of stones as a guide to the engineer who will superintend the borings. These are marked with an asterisk. As a rule, I have chosen them in such places that the coal should be reached at a moderate depth; but afterwards, if these are successful, other borings might be made at greater distances from the outcrop. In any case, the borings I have indicated should, I think, be made before any expense is incurred in sinking pits.

LIST OF BORING SITES.

Sangar Marg Field.

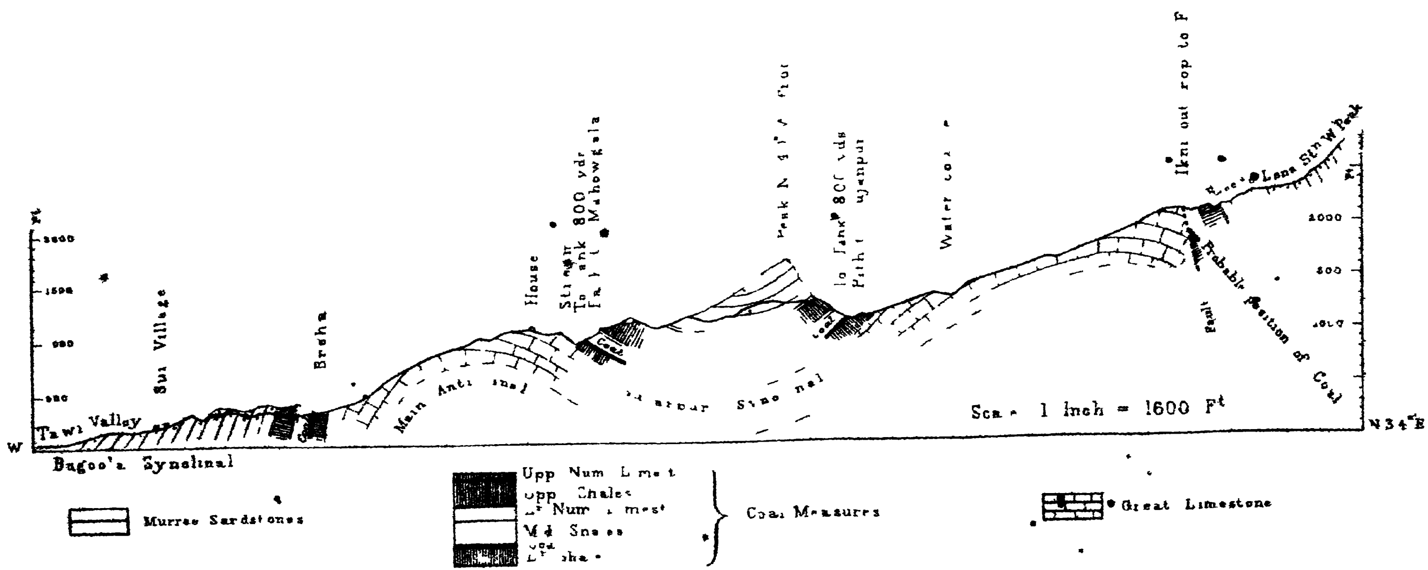
Locality.	Beds exposed at surface.	Direction of dip.	Angles of dip.	REMARKS.
1* Kroli village, at side of path on *col* leading to Tawi valley.	C.M. upper shales	S.W.	67°	Coal exp. about 80 ft. to N.
2. Kahiar village, in ravine to E. of village.	M.S.S.	S. 20° W.	62°	
3* About 500 yards S. of Ransu village, on path from Berh to Kotla at side of small stream.	M.S.S.	?	?	Rocks at surface not well exp.
4. Near conical hollow on fields about 200 yards S.W. of Ransu.	.....	...	...	Rocks concealed by cultivation.
5. In bed of Tawi stream by 2nd mill below gorge at Ransu.	......	...	...	Rocks concealed by boulders in river.
6* Bugoola valley, about 300 yards S.W. of Kori, Gulabgarh fort W. 7° N.	M.S.S.	S.	50°	
7* Between Kori and Ransu, about 30 ft. S. of path on top of *col*.	C.M. middle shales.	S.	40°	
8. Brehal side of stream about 100 yards S. of coal outcrops.	C.M. upper shales	S.	70°	
9* Chakar in ravine about 500 yards W. of tank, Lena Stn. N. 30° E.	C.M. lower portion of upper shales.	N. 20° E.	30°	
10* Chakar, about 300 yards N. of tank, Lena stn. N. 25° E. Peak above Berh S. 35° W.	Do. do. do.	Approx. h	orizontal	

Mehowgala Field.

Locality.	Beds exposed at surface.	Direction of dip.	Angles of dip.	REMARKS.
11* In valley N. of Acker village, about 1½ miles from Neari Tawi Mehowgala due W.	C.M. near top of upper shales.	S. 25° E.	44°	
12* In bed of Neari Tawi, about 100 yards below crossing of path from Acker to Mehowgala	C.M. top of middle shales.	S.	36°	
13* W. of Mehowgala village, where path to Siro turns S. along base of scarp of M.S.S.	Base of M.S.S.	W.N.W.	6°	
14* In ravine on path to Siro from Mehowgala.	C.M. top of upper shales.	Approx. h	orizontal	
15* In same ravine E. of Siro village	C.M. upper shales	Do.		
16* On left bank of Siro stream below the village near junction with small stream from W.	C.M. upper shales	S.S.W.	17°	
17* About ½ mile W. of Siro village in valley of small tributary stream.	C.M. upper shales	Approx. h	orizontal	

M.S.S. = *Murree Sandstones.* C. M. = *Coal measures.*
N.B.—The bearings throughout are *compass bearings.*

SECTION ACROSS SANGAR MARG COAL FIELD FROM BREHAL TO LENA STN



RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1888. **[August.**

The Manganese-iron *and* Manganese-ores *of* Jabalpur, *by* PRAMATHA NATH BOSE, B.Sc., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With 2 maps.)[1]

The *pyrolusite* of Gosalpur was first brought to the notice of Government by Mr. W. G. Olpherts in 1875. It was examined in 1879 by Mr. H. B. Medlicott, late Director of the Geological Survey, and a note on the ore, with an analysis of it by Mr. Mallet, was published in the "Records" of the Survey for that year (Vol. XII, p. 99). Four years later Mr. Mallet examined the iron-ores of the northern portion of the district of Jabalpur. In his very valuable and comprehensive paper on those ores ("Records," Vol. XVI), there is a brief notice of the Manganese-ores of Gosalpur. He was, I believe, the first to point out the existence of *psilomelane* in association with manganiferous hematite, the latter forming a band in the Lora group[2] at Gosalpur and Khatola.

In 1884 Mr. C. W. McMinn, then Deputy Commissioner of Jabalpur, sank a number of pits to ascertain the extent of the manganese-ores at Gosalpur. In the same year Dr. King, the present Director of the Survey, paid a hurried visit to the place from Jabalpur. During the Durga Puja holidays last year, the ores were further explored by Mr. E. J. Jones of the Geological Survey. After Mr. Jones' return, I was deputed by the Director about the middle of October last to continue the exploration.

On arrival at Gosalpur, I found a number of pits and trenches excavated by Messrs. McMinn and Jones, of which Mr. McMinn's pits had been partially filled up. I had these cleaned, and, where necessary, deepened, and started a number of fresh excavations in different parts of the village. I found that the *pyrolusite* occurred in

[1] Map 1 only published now: Map 2 will appear in next number of the Records.

[2] One of the groups into which the Bijawar formation has been divided, called after the Lora range near Sihora. (*Vide* Records, Vol. XVI, p. 96.)

and among quartzites,[1] which were subsequently found to invariably accompany the Lora group, forming probably its base, and which, for the sake of convenience, I have designated as Gosalpur quartzites. I found, also, that the Lora group formed a distinct synclinal just west of Gosalpur, the manganiferous and other Lora strata which crop out here re-appearing in the Chakrandha hill, a mile and a half west of Gosalpur, but with the dip reversed. With these clues I traced the *psilomelane* and *pyrolusite* over a rather wide area, included partly in Sihora and partly in Jabalpur Tahsil. But though spread over such a large area, the quantity of *pyrolusite* does not appear to be so great as might be expected. I must observe, however, that none of the localities was searched so minutely as Gosalpur; and that the present report is to be taken rather as indicating the directions in which *pyrolusite* or *psilomelane* is to be looked for, than as giving an exact, or even an approximately exact, estimate of the ore-bearing capabilities of the entire area. However, enough has, I venture to think, been done for exploration purposes in the northern portion of the Bijawar ground. With regard to the southern Bijawar ground, west and southwest of Jabalpur, I had time only to pay a hurried visit to it. I found *psilomelane* in the Lora group at Nonsar, 12 miles north-north-west of Jabalpur, on the road to Patun. The Lora group also occurs at Gangai (a short distance south of the Marble Rocks near Jabalpur); and it is possible that both *pyrolusite* and *psilomelane* will be found in it. I would recommend that the unspent portion of the manganese exploration fund, amounting to R75-7, be devoted to the exploitation of this area.

The Central Provinces Government made a grant of R500 for the manganese exploration at Gosalpur. When I found that the ores extended far beyond this place, I tried, by exercising strict economy, to make my work cover the entire area without exceeding the grant; R450 only was drawn by me, and of this amount an unspent balance of R25-7 has been deposited with the Deputy Commissioner of Jabalpur.

I have to record my thanks to Messrs. C. W. McMinn and F. C. Anderson, Commissioner and Deputy Commissioner, respectively, of Jabalpur, when I started work, for the readiness with which they gave me every assistance that lay in their power. The Director paid an inspection visit while the exploration was in progress; and, if it may be called successful in any sense, not a little of the success is owing to his guidance and encouragement.

I have in this report tried to present the economic results of the exploration. Observations which are chiefly of theoretical interest will be discussed in a separate report, which will be submitted to the Director later on.

I. MANGANIFEROUS HEMATITE AND PSILOMELANE.

A.—MANGANIFEROUS HEMATITE.

The manganiferous hematite is confined almost exclusively to the Lora group. There is one doubtful occurrence, which will be specially noticed hereafter. The normal and original form of the ore appears to be that known as micaceous-iron-ore, layers of which are interbanded with thin jaspery quartzites, both contorted together,

[1] There is one exception, see p. 82.

and the former curiously following the flexures (which are sometimes very sharp) of the latter.

The micaceous-iron-banded quartzite, *i.e.*, quartzite with interbedded layers of micaceous hematite, is generally too poor to be worked profitably. But at places the micaceous-iron-ore is very rich, the quartzite element being entirely, or almost entirely, wanting. This richness usually takes place on comparatively low ground. The highest points of the ridges are almost invariably formed of contorted quartzites with layers of micaceous hematite.

When the micaceous-iron-ore is very rich, as at the foot of Santok hill (Gosalpur), the rock may be called a micaceous-hematite schist. Such micaceous-hematite schist was seen in the direction of the strike, as well as across it, to pass into the folded quartzose rocks with thin layers of the ore at Dharampur and elsewhere.

The micaceous hematite sometimes passes almost imperceptibly into manganiferous hematite, which appellation is here given to hematite in which the presence of manganese is discernible with the naked eye, for there can be hardly any doubt that this mineral is also present in the micaceous hematite, though as mere traces. In proportion as the micaceous-iron-ore becomes manganiferous, it loses its characteristic micaceous lustre, and becomes more earthy-looking and massive. The shales interstratified with, and overlying, or underlying, the micaceous-iron-banded quartzites are also frequently impregnated with manganiferous hematite in varying degrees of richness.

The manganese in the manganiferous hematite is usually present as nests and thread-like veins of *psilomelane*, besides being disseminated in the matrix.

In the Lora hill area (in which I include the entire area stretching from Daimapur to Murhasan), manganiferous hematite in workable quantity was found at the following localities:—

I.—*Dharampur* (*including Hirdenagar*).—Close to the boundary between this village and Deonagar, on the western slope of the ridge running south-west from Gosalpur, a trench exhibited the following section (commencing at the north-western end):—

8′ Soft whitish talcose slaty shales *(chuhi)* dipping north-north-west.
18′ Obscured.
11′ Shales.
18′ Obscured.
32′ Decomposed earthy rocks with traces of micaceous hematite.
24′ Obscured.
13′ Whitish shales with a little micaceous hematite.
28′ Shaly and quartzose rocks with some micaceous-iron-ore.
15′ Micaceous hematite.
3′ Banded jaspery-looking rock, with limonite towards surface, dipping N. 35 W.
6′ Obscured.
78′ Soft, thinly-stratified, whitish and yellowish talcose shales.
13′ Obscured.
32′ Micaceous manganiferous hematite.
10′ Shales impregnated with *psilomelane*.

A trench three-quarters of a mile north-east of this trench, on the road from

Tola Hirdenagar to Dharampur showed the following section, commencing at the north-western end (about 57 feet from it) :—

12′ Massive limonite, with segregated *psilomelane* at the surface.
5′ Shaly rocks.
12′ Shaly rocks (rather thick-bedded) with some manganiferous hematite.
33′ Shales (partly obscure).
6′ Manganiferous hematite with *psilomelane.*
16′ Shales with a little micaceous iron-ore.
17′ Manganiferous hematite.
12′ Soft, decomposed, earthy rocks, with micaceous iron-ore.
25′ Soil to a depth of 4′ with fragments of micaceous iron, manganiferous hematite, &c.
6′ Obscured.

A trench about three-quarters of a mile east of the village of Dharampur, and close to the boundary between it and Murta (a deserted village), exhibited a rather rich deposit of manganiferous hematite. Commencing from the north-western end the cross-cut gives the following section :—

28′ Micaceous-iron-banded quartzite (poor).
4′ Manganiferous hematite (with massive *psilomelane* at the surface).
88′ Micaceous-iron-banded quartzite (poor).
30′ Schistose micaceous iron (rather rich).
14′ Micaceous-iron-banded quartzite.
8′ Obscured.
2′ Schistose micaceous iron (rich) apparently much 'crushed,' with abundant *psilomelane.* [The dip observed so far points N.N.W.]
12′ Obscured.
11′ Manganiferous hematite, very rich in *psilomelane,* apparently much crushed.
33′ Micaceous hematite at places rich in *psilomelane.*

A pit dug at this end showed (from the surface)—

2′6″ Large blocks of apparently much crushed manganiferous hematite with abundant *psilomelane.*
3′ Schistose micaceous iron with a little *psilomelane.*

Another pit, 24 feet south-east of last showed from the surface—

2′6″ Large blocks of *psilomelane.*
2′6″ Large blocks of *psilomelane* (but harder) with bits of micaceous hematite.
4′ Schistose micaceous hematite.

II. Gosalpur.—A cross-cut here, a little less than half a mile north-west of the dâk bungalow, gave the following section, commencing a few feet from the north-western end :—

6′ Manganiferous hematite (very rich). *Psilomelane* in large botryoidal masses at the surface.
13′ Manganiferous hematite gradually becoming poorer, southward.
5′ Obscured.
18′ Soft micaceous iron-ore.
8′ Micaceous-iron-banded quartzite. [The dip so far appears very high and points to N.N.W. to N.W.]

25′ Obscured.
43′ 'Crushed' quartzoze rocks with manganiferous hematite, rather rich at places.
8′ Micaceous-iron-banded quartzite.
43′ Schistose micaceous hematite with a little *psilomelane*, dipping N.N.W. 60°.

The cross-cut at the northern edge of the ridge north-west of the dâk bungalow, locally known as Santok hill, about a quarter of a mile north of the bungalow, gave a good section. The trench was dug partly by Mr. McMinn and partly by Mr. Jones. It was deepened by me at places. Commencing at the north-western end the section is as follows :—

7′ Reddish and purplish slaty shales, dipping 55° N.W. by N.
4′ Manganiferous hematite with thin veins of *psilomelane*. The surface of the hematite bed is botryoidal at places, the *psilomelane* veins following the contour of the concretions.
35′ Soft, talcose shales, at places impregnated with iron-ore.
28′ Schistose, micaceous hematite.
8′ Same as above, but blacker, more massive-looking, richer, and with occasional veins and nests of *psilomelane*.
12′ Schistose micaceous hematite.
8′ Micaceous hematite partly with veins and nests of *psilomelane*.
22′ Argillaceous rocks, with some micaceous hematite.
42′ Mottled quartzose rocks more or less obscured at places.

III.—At Pahrewa (a mile and a half south of Sihora) and at Khatola, the manganiferous iron-ore is fairly rich at places. Close to the boundary between Sukra (a deserted village just east of Khatola) and Surda, a trench gave the following section, proceeding from its north-western end :—

230′ Manganiferous hematite, very rich at places.
24′ Covered up.
21′ Manganiferous hematite.
27′ Obscured.
15′ Schistose micaceous hematite.
8′ Obscured.
17′ Micaceous-iron-banded quartzites, much folded and crumpled.

IV. Gogra.—Along the southern slope of the Lora range the manganiferous ore is very rich at places. It is especially so at Gogra, close to, and at, the boundary between this village and Danwai. There are some mines here which have for some time past been supplying the furnaces of the entire neighbourhood.

V.—Mangela (a deserted village).—Here, too, the ore appears to be rather rich. There are some old mines here.

With regard to the other outcrops of the Lora group, manganiferous hematite does not appear to be present, at least to any considerable extent, in the band stretching from south of Chattarpur to Saroli, as well as in the Lamehra range of hills. I am not also aware of its occurrence in the outcrop south-west of Bhera Ghat. Neither of these bands, however, was closely searched.

In the Lora patch at Nonsar (12 miles north-west of Jabalpur, on the road to Patan) manganiferous hematite was found to exist.

B.—PSILOMELANE.

This mineral is present, as has been already mentioned, as fine thread-like veins in the manganiferous hematite. Sometimes a bed of this hematite has developed on it botryoidal concretions, which increase in size towards the surface so as to become large mammillary masses. The *psilomelane* veins follow the contour of the concretions, and increase in number and thickness towards the outcrop, so as to appear as nearly mammillary masses of pure *psilomelane* at the surface.

This kind of change was specially observed to take place in the comparatively thick shaly strata overlying the micaceous-iron-banded quartzite. The development of *psilomelane* in these was found associated with that of milk-white quartz rocks at some places.

In the manganiferous hematite, formed evidently by the local concentration of disseminated *manganese* in the schistose micaceous-hematite, *psilomelane* usually appears as thin veins, parallel to bedding or filling small fissures, &c. Sometimes an outcrop of micaceous-hematite schist, with dip and strike quite distinct, is abruptly overlaid by botryoidal or mammillary masses of pure *psilomelane*. Usually, however, there intervene between the two a mass of variable thickness composed of bits of manganiferous hematite cemented together by a matrix of *psilomelane*, the whole mass looking as if the hematite had been crushed, and the broken fragments subsequently welded together by the manganese-ore. This is the view held by Mr. Mallet. Wherever, however, the apparently crushed mass was dug into, it was found to pass gradually downward, within sometimes not more than 4 or 5 feet from the surface, into strata which showed no signs of crushing at all, and which, in fact, at places, as at Murhasan, were found to dip rather easy. This appearance of "crushing," at or near the surface, may, it appeared to me, be attributed to surface disintegration of the micaceous-hematite previous to the deposition of *psilomelane*; or, as suggested by Dr. King, to the expansive force exerted during the development of *psilomelane*; or in part to both.

Psilomelane co-exists with manganiferous hematite; and the places where the latter has been found in abundance are also the localities where the former occurs in any quantity.

At Murhasan, there occur thinly-stratified quartzites without any interbedded micaceous hematite. They are superposed by massive quartzose beds which are highly ferruginous. There is considerable twisting of the strike, and the rock which crops out has an appearance of being very much crushed. The shivered fragments of quartzite are cemented by *psilomelane*, and at one spot by *pyrolusite* as well.

At Ponri (4 miles west of Sihora) banded quartzose strata without any micaceous hematite, similar to those just mentioned as occurring at Murhasan, considerably twisted, have developed in them, towards the surface *psilomelane* as thin veins, fillings in of fissures, &c. The *psilomelane* does not appear to go down more than 4 or 5 feet from the surface. The quartzite appears to be converted towards the surface partly into limonite and partly into *psilomelane*. The *psilomelane, in situ*, is very much mixed up with the matrix of the quartz-rock, but nodules of it found along the hill slope are nearly free from it. This fact of the nodules of detrital ore being much richer than the ore *in situ*, was observed almost everywhere. Sometimes blocks rich in

manganese-ore were found along hill slopes, but the search for the ore *in situ* from which the blocks may have been derived proved fruitless.

The quartzose strata after an interspace of about a mile re-appear north-east of Darsani, richly impregnated with *psilomelane* and other manganese-ores. They form a ridge running in the direction of strike for about 2 miles. The manganese and iron-ores here are very much mixed together. The former predominate in the hill just north-east of Darsani, as also on Kasai (or Kushi) hill. A pit opened on the south-eastern slope of the former exhibited some 16 feet of the ore, which appears to be mostly *psilomelane*. In the Kushi hill a distinct syncline was observed. This hill will be again noticed in connection with *pyrolusite*. The quartzose strata of Ponri, Darsani, and Kushi hill probably belong to the Lora group, and have, in all likelihood, come up by an anticlinal flexure.

A large quantity of *psilomelane* in the form of nodules occurs at Gosalpur (Area *b*, Map of Gosalpur). And a little of the mineral in intimate association with *pyrolusite* also occurs at this place and elsewhere.

From the mode of occurrence of *psilomelane* it is impossible to form anything like an estimate of the quantity present. The quantity of pure *psilomelane* cannot be very great, as it is chiefly confined to the surface. Still it is probably greater than that of *pyrolusite*. The quantity of manganiferous hematite, with veins and nests of *psilomelane*, must, however, be regarded as practically inexhaustible.

An assay of an average specimen of the manganiferous hematite (from Danwai mine) made by Mr. Mallet, gave the following result (Rec., Vol. XVI, p. 101):—

Ferric oxide	66·33	Iron 46·43
Manganese (with traces of cobalt)	12·26	
Oxygen	6·83	
Phosphoric acid	·27	
Sulphuric acid	·03	
Sulphur	trace	
Ignited insoluble residue	9·55	
Lime, alumina, water and undetermined	4·76	
	100·03	

The ore would be useful for the manufacture of steel. At present it is used for the manufacture of a kind of a steely iron, known as *khari*. A brief account of the *khari* industry will be found in Note A.

A specimen of *psilomelane* analysed by Mr. Mallet yielded 83·20 per cent. of the available peroxide.

II.—PYROLUSITE.

Its distribution is generally co-extensive with that of the Gosalpur quartzites.[1] At places, however, the mineral is present as mere traces. It was found in any quantity at the following localities:—

1. *Gosalpur*—Except in the ground just in front of the dâk bungalow (some 50 yards to south-east of it), the *pyrolusite* occurs here in and among the Gosalpur quartzites, usually soft, decomposed, and blue-coated at the outcrop. Sometimes the rock is hard, and either white or red in colour, assuming in the latter case the

[1] A band underlying, and probably forming the base of, the Lora group.

appearance of jasper. Wherever such is the case, manganese-ores are wanting. Frequently the rock appears as a conglomerate or breccia, fragments of soft, decomposed (sometimes almost powdery) quartzite being cemented together, as it were, by a matrix of *manganese* or iron-ore. Wherever such a rock crops out, *manganese* or iron-ore is found in some quantity by digging close to it through the soil-cap under which it passes, the nature of the ore being determined by that of the "matrix" at the outcrop.

The quartzites have the general Bijawar strike of the area, *viz.*, N.E.-S.W., The dip is obscure; it was found to be very high (about 80°) pointing S.E., some 150 yards north of the dâk bungalow.

The details of some of the sections as exposed by the pits (see Map of Gosalpur) at this place may not be uninteresting. The great majority of them may be grouped in two lines, 250 to 500 feet apart, running nearly E.—W., roughly parallel to each other.

Commencing with Pit No. XIII, at the western extremity of the southern line of pits, the sections are as follows:—

Pit XIII.

1′5″ Soil with grains and nodules of iron-ore.

6′ Large blocks of hematite, some with fragments of decomposed quartz rock passing below into decomposed quartzites with veins of hematite.

Pit XIV.—One hundred and seventy-five feet east-north-east of last pit. It is an old, large, squarish pit, measuring 23 feet east to west. At its northern end there is an outcrop of the Gosalpur quartzites, either coated blue or having the appearance of a "breccia," such as has been described above. The pit was deepened at two ends to 30 feet at the western, and 12 feet at the eastern end.

1′ Soil with blocks of quartzite.

1′ Grains and nodules of iron-ore, with a few occasional grains of *pyrolusite* and fragments of quartzite.

5′6″ Abundant *psilomelane* in flat, platy masses, with which are associated *pyrolusite* and hematite as grains and nodules.

The shaft at the western end of the pit disclosed below the last-mentioned layer a thickness of—

22′6″ of decomposed, rotten, crumbly, whitish, yellowish, and mottled speckled quartz-rock with veins and nests of *pyrolusite*, passing below into similar decomposed speckled rock, but without these veins and nests. Small pockets of well-crystallised *pyrolusite* were found, however, in the latter at various depths. The speckled appearance is due to the presence of brownish specks, which will be described hereafter.

Pit XIX.— Two hundred and twenty-five feet to east of last—

6″ Soil.

3′6″ Platy, flat and botryoidal masses of *psilomelane*, with some *pyrolusite* (the former predominating largely), and grains and nodules of iron-ore.

4′ Decomposed yellowish and mottled quartz-rock, with veins and nests of *pyrolusite* and *psilomelane.*

Pit XV.—Fifty feet east of last—

1′ Soil.

4′ Nodules and grains of iron-ore, and of *pyrolusite* largely associated with *psilomelane*.

4′6″ Yellowish decomposed quartz-rock with nodules of earthy-looking *pyrolusite* (?).

3′ Yellowish, decomposed, quartz-rock, with veins and nests of *pyrolusite* (?), which disappear towards bottom.

Pit III.—Two hundred feet east-south-east of last—

1′ Soil.

6″ Nodules and grains of iron-ore, with a little *pyrolusite* towards base.

3′ Grains and nodules of iron-ore and of *pyrolusite*, the latter measuring ⅛″ to 2″ across, and associated with *psilomelane* (but not so largely as in the previous pits).

3′6″ Decomposed quartz-rocks with grains and nodules of *pyrolusite*.

Pit XXVIII.—One hundred feet east of last—

3′ Soil.

2′6″ Nodules and grains of *pyrolusite* and of iron-ore, the former averaging probably less than ½ inch in diameter.

1′ Large blocks of very good *pyrolusite*, somewhat spongy in texture, with cavernous spaces occupied by yellowish, decomposed quartz-rock.

1′2″ Decomposed yellowish and yellowish-white mottled quartz-rock, with veins and nests of *pyrolusite*.

Pit XXXI.—One hundred and ten feet east of last.—This is one of three pits sunk in a large, old, partially filled-up pit, from which *pyrolusite* used to be raised of old by glass-makers.

2′ Soil.

2′8″ Abundant nodules of *pyrolusite*, ¼ inch to 6 inches in diameter, mixed up, as usual, with nodules of iron-ore. A little *psilomelane* and *wad* occurs in association with the *pyrolusite*.

4′10″ Fragments of decomposed yellowish, and yellowish-white, mottled quartz-rock, becoming larger and more abundant towards bottom. *Pyrolusite* occurs in the interstices in larger blocks than in the preceding stratum and with cavernous spaces containing the decomposed quartz-rock.

Decomposed quartz-rock with veins and nests of *pyrolusite*.

Pit XLVI.—Seventy-five feet south-east of last—

2′4″ Grains and nodules of iron-ore.

3′10″ Yellowish and brown mottled ferruginous grit, or gritty clay, in large blocks.

6″ Spongy nodules of *pyrolusite* with decomposed quartzite.

Pit XLVII.—Fifty feet south-east of last—

9′ Yellowish and brown ferruginous grit, or gritty clay, without a trace of *pyrolusite*. The rock was found so hard that it had to be blasted.

Pit XXV.—Five hundred feet east-north-east of last, in the Bazar.

3′ Soil.

4′4″ Hard, yellowish loam, with grains of *pyrolusite* and iron-ore.

12′ Nodules and grains of iron-ore, at places compacted into large, hard blocks with abundant oolitic grains (internally black, *pyrolusite* ?), and a few large nodules of hematite and of *pyrolusite*.

Decomposed quartzite with veins and nests of hematite.

Farther east, a section, some 20 feet in thickness, is exposed in an old *baoli*, opposite the police station. The entire depth consists of ferruginous, more or less cellular, gritty clay (Laterite).

The northern line of the more important pits alluded to before may be taken to commence with Pit XX, 225 feet north-west of Pit XIII (the westernmost one of the southern line of pits just described).

4′ Soil with small grains and nodules of *pyrolusite*, averaging ½ inch in length, and big lumps of hematite (some with segregations of *pyrolusite*).

2′8″ Decomposed, crumbly, yellow and white mottled quartzite.

Pit XXXV.—One hundred and seventy-five feet east-north-east of last—

4′ Soil with fragments of quartzite, and grains and nodules of *pyrolusite* and of hematite (a little *pyrolusite* and *psilomelane* being associated with the latter). The nodules, as usual, are generally of a spongy texture.

Pit XXII.—Five hundred and seventy-five feet east of last—

9″ Soil with small grains and nodules of *pyrolusite*.

1′9″ Abundant *pyrolusite* in nodules, and small angular and irregular plates, with fragments of quartzite and grains and nodules of iron-ore.

1′6″ Large blocks of *pyrolusite* with decomposed quartzite.

1′ Blocks of yellow and mottled decomposed quartzite with *pyrolusite*, occupying interstices between them.

Pit XLIII.—Two hundred and fifty feet east of last—

8″ Soil.

5′ Nodules and grains of iron-ore and fragments of quartzite. Towards bottom, large spongy blocks of hematite with decomposed quartzite.

Decomposed quartzite.

Pit XXVI.—Six hundred and twenty-five feet east-north-east of last—

8′ Small grains and nodules of iron-ore with big lumps of hematite of a spongy texture, associated with a few small nodules of *pyrolusite*, the latter being quite subordinate.

2′6″ Decomposed yellow and white quartzite, with veins and nests of hematite and *pyrolusite* (?).

The ground lying to east of this pit is covered by nodular iron-ore compacted into hard rock (Laterite), forming a somewhat high ground. At the foot of this ground, 1,075 feet east-north-east of Pit XXVI, an outcrop of quartzite was met with in Pit XXVII, with veins of hematite. In a well, a few yards from this pit, reddish and white mottled quartzose shales were met with at a depth of 4 feet from the surface.

North, south and east of the area enclosed by the two lines of pits described above, the ground is covered by nodular iron-ore usually compacted into hard rock. Some pits were sunk into it. Several in the northern portion of the ground, disclosed, at a depth of about 9 feet or so, decomposed quartzites similar to the rocks invariably found at the bottom of the pits described above when deep enough.

In the ground west and north-west of the dák bungalow, the rock found below the nodular iron-ore (which is of small thickness) is a ferruginous, red and yellow and brown grit or gritty clay, similar to that found in Pit XLVII. About 50 yards

east and south-east of the dâk bungalow, a few fragments of slaty-looking micaceous hematite were found mixed up with the nodular iron-ore. A trench varying in depth from 6 to 12 feet, disclosed the former rock *in situ*, but to all appearance very much crushed, fragments of it being held together by a ferrugino-*manganiferous* cement. This rock passes into a laterite-looking rock containing iron-ore and *manganese*-ore (*pyrolusite* intimately associated with a little *psilomelane* and iron-ore) in which not a trace of the micaceous hematite was observable. A large quantity of *manganese*-ore was raised from this trench. That its occurrence, however, is exceptional, is evidenced by the following section disclosed by a pit (XVI) in front of the bungalow, not many yards from the trench just mentioned :—

5′ Nodular iron-ore.
8′ Blocks of hematite with bits of micaceous iron-ore.
10′ Soft, earthy, micaceous hematite.
4′ Compact and very hard red hematite, so hard that it had to be blasted.

The *pyrolusite* area of Gosalpur is divisible into five portions (see Map 1) :—

(*a*) Stretching east-west from Pit XLVI to Pit XV, and north-south from a point a few yards north of Pit XXII to a point between Pits III and XV. Here the *pyrolusite* is the predominating mineral, *psilomelane* and iron-ores being quite subordinate to it. The greatest thickness of the ore-bearing stratum (leaving out of consideration the quartzites with veins and nests of *pyrolusite* as unworkable with profit) is 7 feet 6 inches (Pit XXXI), and the least 1 foot (Pit XXXIII, not described above). The former thickness is, however, somewhat exceptional, and the mean should probably be taken at not more than 3 feet 6 inches. Towards the surface, the *pyrolusite* nodules are mixed up with those of iron-ore, and towards bottom, they contain a good portion of the matrix of the quartzite, in which it occurs as veins and nests deeper down. The quartzite is, however, much decomposed, loose and crumbly, and is, therefore, easily separable. Making allowance for it and for the grains and nodules of iron-ore, it would not be safe to take the thickness of pure *pyrolusite* (associated with a little, but very little, *psilomelane*) at more than 1 foot 6 inches.

The greatest length of the principal *pyrolusite* area is 525 feet, and the greatest breadth 338 feet. The area is about 157,500 square feet. There are several small outcrops of the Gosalpur quartzites within this area; and the *manganese*-ore is present in them as mere traces. The area covered by them cannot be less than 20,000 square feet. Applying this correction, the estimated *pyrolusite* area would be reduced to 137,500 square feet. Thus the quantity of *pyrolusite* present here would occupy $137{,}500 \times \frac{3}{2}$ cubic feet = 206,250 cubic feet.

The specific gravity of an average specimen of the *pyrolusite* from this area, determined in the laboratory of the Geological Survey, was found to be 4·7. Thus the weight of the quantity available here would amount to 27,000 tons (about).

It should be observed that a portion of this amount (by no means inconsiderable) has been taken away from the old pit (the richest portion of the ground between Pits XXX and XXXI) by glass-makers and others; and that a portion has been raised from the trial excavations successively made by Mr. McMinn, Mr. Jones and myself, and is lying at the place.

The cost of raising the ore is trifling, as it occurs at a very low depth from the surface, and can be dug out with facility. It should, however, be observed, that

a large portion of the ore occurs in small grains, coated red by oxide of iron; and the sifting of these from similar grains of iron-ore needs time, care, and experience. The proportion of larger blocks and nodules of *pyrolusite*, measuring from nearly a foot to half an inch in length to smaller grains was found in Pit XXVIII to be nearly 1 to 3. So that the former kind of ore in the area under consideration does not probably amount to more than 9,000 tons. Of this amount, that already removed may be put down at about 500 tons, if not more. So that the quantity still available of the larger nodules of the ore (above half an inch in length) probably does not exceed 8,500 tons. This estimate is no doubt very vague, and it is given here, as it may give a better idea of the quantity of the ore available than mere guesses.

(*b*) In this area, the *psilomelane* either predominates over the *pyrolusite*, or the two minerals are present in about equal proportion. It stretches south-westward from Pit XV. Its length may be taken at about 470 feet, and breadth at about 80 feet. Thus the area may be estimated at 37,600 square feet. Making allowance for an outcrop of the Gosalpur quartzites, in which the *manganese*-ores occur as mere traces, or do not occur at all, this estimate would be reduced to probably 24,000 square feet. The greatest thickness of the ore-bearing stratum is 8 feet 6 inches (Pit XV), and the least 3 feet 6 inches (Pit XIX). A mean of 5 feet may, I think, be safely taken. The ore, however, is mixed up with grains and nodules of iron-ore. Making allowance for these, the manganese-ore (*pyrolusite* and *psilomelane*) may be taken to occupy a thickness of $2\frac{1}{2}$ feet. Thus the volume of the manganese-ore would amount to $24,000 \times \frac{5}{2} = 60,000$ cubic feet.

Of this volume not less than half, probably more, say, about three fifths, would be occupied by *psilomelane*. The cubic contents of the *pyrolusite* would thus be about 24,000 cubic feet. Taking its specific gravity at 4·7, it would amount to 3,000 tons (about).

If allowance be made for small grains of *pyrolusite*, this quantity would be still further reduced.

(*c*) (*c*[1]) Two detached areas, one situated north of (*b*), and the other in the village, are included in these divisions. Here the *pyrolusite* is present as nodules or small grains, quite subordinate to similar nodules and grains of iron-ore (hematite, &c). From pits XXV and XXVI (inside the village) only a few nodules of *pyrolusite* of any size were obtained, it being present chiefly as oolitic grains, too small probably to be profitably sifted from similar ones of oxide of iron (both being coated red outside), and worked for purposes for which pure, or tolerably pure, *pyrolusite* is required. It is impossible to form even such a vague estimate of the quantity of *pyrolusite* present in these two areas as has been given for (*a*) and (*b*). It would probably not amount to more than what has been estimated to occur in (*b*).

(*d*) In front of the dâk bungalow, by the road leading from it to the Mirzapur road. Here the *pyrolusite* occurs in "lateritised" micaceous hematite. The iron and manganese-ores are greatly mixed up (the former appearing to predominate). However, a large quantity of blocks and nodules of *pyrolusite* was raised from the trench mentioned before. The area covers about 40,000 square feet. The thickness of the *pyrolusite* may be taken at a fourth of the entire thickness, which is over 12 feet. Thus the cubic contents of *pyrolusite* here would amount to about 120,000

cubic feet. Taking specific gravity at 4·7, the quantity would be about 15,000 tons. The *pyrolusite* here is invariably and intimately associated with a little *psilomelane* and a little iron-ore. The whole of the ore, however, occurs in large blocks and nodules.

Thus the total quantity of *pyrolusite* occurring at Gosalpur may be roughly estimated at about 50,000 tons. It must be remembered, however, that it is almost invariably associated with a little *psilomelane*, and that a good portion of this quantity consists of very small grains, mostly coated red outside by oxide of iron.

2. *Keolari* (*a deserted village*).—There is an outcrop here of what appeared to me the Gosalpur quartzite, a mile nearly due south of the dâk bungalow at Gosalpur. The quartzite runs parallel to a band of "lateritised" micaceous hematite, similar to that occurring in front of the Gosalpur bungalow, but without any *pyrolusite* as far as ascertained by a trench dug close to the road leading from the Mirzapur road to Khumarea. The quartzites are surrounded, as at Gosalpur, by nodular iron-ore compacted into large, hard blocks at places. Their outcrop is about 600 yards long and 150 yards broad. At the north-eastern edge of it, where they pass under alluvium, some pits were sunk, which disclosed a large quantity of manganese ores. A good portion of these is *wad*; very little *pyrolusite* was found.

3. *Murhasan*.—This place is situated at the south-eastern extremity of the eastern portion of the Lora Syncline.[1] At the northern edge of a hillock just west of the village, apparently much crushed quartzites crop out with veins and nests of *pyrolusite*. A pit here exposed a thickness of 3 feet of large nodules of *pyrolusite* of a somewhat spongy texture, passing below into quartzose rock with a network of veins of *manganese-ore* as in the Gosalpur pits. The *pyrolusite* is associated with *psilomelane*; and the rest of the hillock is constituted of contorted Lora strata in which the latter mineral is alone found. The *pyrolusite* area here is probably not more than 625 square feet in extent. Much of the ore, however, is mixed up with the quartzite in which it occurs. The quantity of *pyrolusite* here would not probably exceed 200 tons.

Proceeding north-eastward from Gosalpur along the eastern side of the Lora syncline, the next notable occurrence of *pyrolusite* is at 4.—*Pahrewa*, a mile and a half south of Sihora. The mode of occurrence of the ore here is somewhat similar to that at Murhasan. It was found on a conical hillock just south of the village (which is very nearly deserted) to the left of the Mirzapur road. A pit on the western slope of this hillock disclosed 7 feet of decomposed quartzites, with considerable nests and thick veins of *pyrolusite* (associated with *psilomelane*). A trench a few yards north-east of the pit, however, at the top of the hillock, exposed apparently crushed quartzose rocks, micaceous hematite, and manganiferous hematite with veins of *psilomelane*.

5. *Khatola* (*Kuthola on map*).—The *pyrolusite* here occurs in two hillocks formed of the Gosalpur quartzites, close to the railway station. The quartzites are worked for railway ballast, and a portion of the *pyrolusite* has gone with it. I pointed out the ore to the contractor working the ballast pits, and verbally told him

[1] The syncline formed by the Lora group, well seen just west of Gosalpur, and more or less distinctly traceable south-eastward to Murhasan and Kailwas, and in the north-western direction to the Lora range proper.

not to carry it off with the ballast. At one spot, in the smaller of the two hills west of the Saroli road, the *pyrolusite* was found in massive, somewhat cellular, blocks at the surface; digging down, however, it was found to get mixed up with the quartzite. The ore is scattered over a good area. But there is probably no considerable quantity of it, as it is confined to the surface, or occurs chiefly as mere traces.

6. Bhatadon (a mile south east of Khatola, on the south side of the Hirun).—Here the ores occur on a small hillock partly composed of the Gosalpur quartzite and partly of lateritic rock. Exceptionally good *pyrolusite* was found at one spot, free from quartzite-matrix. Digging disclosed a thickness of 8 feet of the ore, but mixed up towards the bottom with the quartzite as at Khatola. A few hundred tons of *pyrolusite* may be expected from here.

7. Hargar ($2\frac{1}{2}$ *miles east of Khatola*).—There is a strong outcrop of the Gosalpur quartzites here. The *pyrolusite* was found to occur as mere traces. It was, however, found in some quantity at the south-western edge of a hill situated between Hargar and Daroli. It occurs in association with iron-ores, and the quantity is probably small.

Traces of *pyrolusite* were found at several spots at Danwai (Dunwie) in the low quartzite hills running parallel to the Lora range. It was found, however, in some considerable quantity at:—

8. Mungeli (*Mungeilee*), *close to the road leading from Sihora to Umaria* (*Oomria*).—Five pits north of the road, at the foot of the hill just west of the village, exhibited an average thickness of 2 feet of *pyrolusite*. At a depth of 4 or 5 feet from the surface it is mixed up with the matrix of the rock which is thin bedded quartzite. Deeper down the rock occurs without the ore, at least visibly. A pit south of the road exhibited under 4 feet of alluvium, 5 feet of quartzose-rock with *pyrolusite*.

Beyond Mungeli, traces of *pyrolusite* were observed at Deori (Deoree), close by the Umaria road in an insignificant outcrop of quartzites.

On the western side of the Lora syncline, the following localities may be noted commencing from the northern portion of the ground:—

9. Chhapra (*Chhota*), *5 miles north-east of Sihora.*—In one of several pits sunk in a hillock a quarter of a mile south of the village, nodules of *pyrolusite* largely associated with *psilomelane* and *wad* and mixed up with blocks and fragments of quartzite, with or without veins and nests of the manganese-ores, were found to a depth of 10 feet from the surface. The quantity of *pyrolusite* here must be very small; and the nodules of it are never quite free from the quartzose rock.

10. Sihora.—At and about this place *pyrolusite* is present in fairly large quantity.

Just north of the encamping ground, a ridge of quartzose rocks runs along the strike north-eastward for a little over 2 miles. At the north-eastern extremity of this ridge traces of *pyrolusite* were found, but the pits dug here did not show any quantity of it. Further search here may prove more successful.

The ridge at places is formed of beds of hematite with interbedded laminated red jasper, passing below (vertically) and laterally (along strike) into quartzose rocks with impregnations of iron ore.

The ridge (which from the villages through which it runs may be called the

Mansukra-Silondi ridge) is scarped on the northern side, the strata dipping south-east. On this (the northern side) a pit exhibited shaly-quartzose strata underlying similar strata impregnated with iron-ore, these last passing under beds of hematite with interbedded jasper. The dip is about 40° south-east. The hematite, at the surface, is largely associated with manganese-ore, which I believe is *pyrolusite*. These mixed manganese-iron-ores are very plentiful in the portion of the ridge (1 mile in length) included within the limits of Mansukra, from the Mirzapur road to the streamlet forming the eastern boundary of that village. At spots the manganese predominates over the iron-ore, and sometimes, but rarely, the former is almost exclusively present. When the latter is the case, the *pyrolusite* is usually of small thickness (2 feet or less) and of small extent, passing vertically below and on all sides into iron-manganese ores, or quartzose rocks containing traces of these.

At one place, about 900 feet west of the boundary line between Mansukra and Silondi, the ore was found to be almost free from iron-ores and quartzose-matrix, and of exceptional thickness. Here almost a solid mass of good manganese-ore (*pyrolusite* intimately associated with a little hematite, and a little, but very little *psilomelane*) goes down to a depth of 11 feet in one of the pits. At this depth hematite with a trace of manganese-ore occurs. From the pits sunk here, the *pyrolusite* was found to cover an area of about 10,000 square feet. Taking its average thickness at 7 feet, there is present here some 70,000 cubic feet of manganese ore. Taking the specific gravity at 4·7, the quantity would amount to about 9,000 tons. From the entire hill some 12 or 13 thousand tons of the *pyrolusite* may be expected. From an assay made by Mr. E. J. Jones, of the Geological Survey, it was found to contain 81·24 per cent. of the available peroxide of manganese.

Inside the town of Sihora, nearly at its northern extremity, on a low ridge formed of cherty-looking quartzites, curiously intermingled with lateritic rock, rather good *pyrolusite* was found at one place. Traces of the ore were also found just west of the town by the road leading from it to Majhauli in an outcrop of the Gosalpur quartzites.

In the compound of the local court-house, where there is an outcrop of the Gosalpur quartzites, a pit showed, below 1 foot 8 inches of soil, a thickness of 12 feet of decomposed quartzose-rocks with nodules of manganese-ore, which appeared to be chiefly *wad*. The ore was mostly raised as a black powdery mass. Another pit, a little to the south, exhibited some 7 feet of quartzites, with veins and nests of *pyrolusite* (?).

11. Naigain.—South of Sihora, the quartzites are lost under alluvium. They re-appear at Naigain on the Hirun river, 2 miles north of Gosalpur. In one of the pits opened here, *pyrolusite* occurs as nodules in decomposed, yellowish quartzites down to a depth of 4 or 5 feet from surface. The quartzite at the surface contains veins and nests of the ore. But I do not expect there is any considerable quantity of it.

Proceeding southward traces of *pyrolusite* were found in the quartzites near Chandnota by the Hirun. The ore occurs in some quantity at,—

12. Dharampur.—A little over a mile west-north-west of this village, at the foot of a hill locally known as Changeli, there is an outcrop of apparently the Gosalpur quartzites, which at one place has the appearance of a breccia, consisting of frag-

ments of quartzite cemented by a matrix of *pyrolusite*. A trench dug close to it showed a good thickness of the ore, but seldom free from quartzite. The thickness was found to be 10 feet in one of the pits. The extent is some 30,000 square feet, if not more. Taking the average thickness at 6 feet, some 180,000 cubic feet of the ore may be expected from here. The ore is, however, as has just been observed, seldom entirely free from the quartzite. Making allowance for it, the quantity of dressed ore may be estimated at about 13,000 tons.

13. Dhangaon.—Nearly at the top of a low hill covered by thick scrub jungle, a mile north-east of this village, and close to the boundary line between it and Tala, an outcrop of quartzites similar to the one just mentioned led me to expect the ore; and it was found, though in thickness and extent it appeared to be poorer than the Changeli find.

14. Chindamani (*Cheendamanee*).—*Pyrolusite* occurs here, as at the last two places, in an outcrop of apparently the Gosalpur quartzites, about a quarter of a mile north-east of the village.

Traces of *pyrolusite* were also found at Kailwas (a mile north of Chindamani), one-third of a mile north of the village, in quartzites.

15. Nurgaon (nearly 4 miles east-north-east of Panagar).—A little over a quarter of a mile east of this village, in a *nala* at the foot of a ridge of Gosalpur quartzites, a small pocket-like deposit of *pyrolusite* was found amongst these. On the ridge, however, the quartzites were found impregnated with iron-ore alone.

16. Pararia (*Purrurea*).—A quarter of a mile east of this village (2 miles south-east of Panagar), there is a ridge of quartzites which have the appearance of being greatly crushed. At one place, at the south-eastern extremity of this ridge, and at its foot, a crust of well-crystallised *pyrolusite* was found on the surface of blackish quartzites. A pit here showed these rocks to be more or less impregnated with the ore. On the ridge, a little to the north-east of this pit, it also occurs, but with considerable admixture of the quartzite.

It is highly probable that the quartzite bands which stretch north-eastward from Nurgaon, and east-north-east from Pararia, if searched more closely than I was able to do, would yield some *pyrolusite*; but, from what I saw, I doubt if it is likely to be of good quality.

17. Kushi (*Kasai*) *hill, 3 miles north-west of Sihora.*—Manganese-ores are very plentiful in this hill. They appear, however, to be chiefly *psilomelane*.

At the south-eastern extremity of this hill, at its top, I observed some massive quartzites identical in appearance with the Gosalpur quartzites, and forming a syncline. Pits opened here exhibited some *pyrolusite* as nests in the quartzites.

Outside the Lora group, and nearer the base of the Bijawars of this area, traces of *pyrolusite* were found in the Majhauli-Bhitri group at the following places[1]:—

(A). CHHAPRÁ (*Bara*), 3 miles south of Sleemanabad.—On the southern slope of a hill, half a mile east of this village, at the boundary between it and Salaiá, I encountered a block of quartzose rock with nests of *pyrolusite*. The hill is covered by cherty rocks in boulder-like masses. Some pits were dug here, but no manganese-ore was found in any of these.

[1] For the places, see Map accompanying Mr. Mallet's paper on the Iron-ores of the Jabalpur district (Rec. Vol. XVI. Part 2).

(B). HARDUA. KHURD (Hurdooa khoord), 12 miles west-south-west of the last place.—A mile north of this village at the south-western end of a ridge of cherty-looking reddish quartzites, traces of *pyrolusite* were observed.

(C). MURAITH (Mooreith), 7 miles north-west of Gosalpur.—Here traces of *pyrolusite* were found in some cherts occurring among chert-banded limestone

With regard to the Bijawar ground south-west of Jabalpur, I had time only to pay a hurried visit to Gangai, 4 miles south of Bhera Ghat. The Lora group occurs here, as has been mentioned by Mr. Hacket in his manuscript report. He notes the presence of quartz-rocks in the western portion of a hill near Dharampur, 3 miles south-west of Bhera Ghat. These rocks may be the representatives of the Gosalpur quartzites in this area. They certainly appear to run parallel to the Lora iron-ore-band, and may, I think, yield some *pyrolusite*.

A carefully selected average sample of the *pyrolusite* from Gosalpur yielded on analysis (Mallet "Man. of the Geol. of India," pt. IV, p. 58):—

Manganese	54·66
Oxygen	31·16
Iron Sesquioxide (with trace of alumina)	4·53
Baryta	3·56
Phosphoric acid	·28
Insoluble in hydrochloric acid	2·74
Combined water	2·41
Hygroscopic water	·28
	99·61

NOTE (A).

Notes on the Iron industry of the Lora hill area.

Nearly every village in the vicinity of the Lora range worked the manganiferous hematite ore at some time or other, as the slag mounds testify. South of the Hirun there were mines at Hirdenagar and Gosalpur. But north of the river, nearly all the furnaces appear to have been supplied by the Danwai mines situated at the boundary between Danwai and Gogra.

Last February, I saw four furnaces at work, two at Karaia and two at Hatwai—two small villages near Kaleri, about 9 miles north-east of Sihora. These four furnaces had been working since November. Two more furnaces were about to start work at Gogra when I visited that place (about the end of February).

The furnace, as usual, is of a most primitive type. It is 4 feet 6 inches in height from the hearth to the throat. The width is 1 foot 6 inches at the hearth, and 7 inches at the throat. The furnace is built of mud, with which some straw is mixed. The making-up of the furnace costs a rupee or so.

The bellows which supply the blast are about a foot and a half high when stretched. They are made up of goat's skins obtained from Jabalpur at a cost of R4 per pair; the making-up costs a rupee. A pair of bellows lasts one full season (November to May).

The entire cost of the furnace and bellows and other requisites amount probably to not more than R7.

The blast is supplied through a pair of clay tuyers, which are renewed every day.

The manganiferous hematite (which is the ore used) is procured from the Danwai mines. The ore has to travel 5 miles for the furnaces at Karaia, and 7 for those at Hatwai. It is carried on pack buffaloes to Karaia at a rate of 2 annas 9 pies for one

day's charge required for each furnace. This includes the cost of digging out and of dressing the ore (*i.e.*, breaking up the bigger lumps into small bits and roughly separating it from the rock matrix which is quartzite). The rate at Gogra, which is only a mile from the mines, is 2 annas per charge.

The fuel used is charcoal. The price paid for it is 8 annas for one day's consumption. This includes carriage. The quantity of charcoal consumed by a furnace in one day averages 4 maunds, so that it costs 2 annas per maund. This price appears to be abnormally low. I was told that it would take 12 men to work regularly for a month to prepare charcoal required for a month by one furnace; that is to say, the remuneration for these 12 men would be R15 per month, or R1-4 per head. There is no doubt that all the 12 men do not work steadily and systematically; and it is probable that 8 men would suffice if they work properly. Even then, however, the wage of a labourer per day would not be more than 1 anna, which is below the normal rate. The charcoal is procured at this low price by making advances to labourers during the rains.

The furnace is worked for 12 hours, from about 8 in the morning to late in the evening. Two men are required to work it, one at the bellows and the other to put in ore and fuel and let out the slag. Their wages vary from 2 to 3 annas each per day.

The furnace is first filled up with charcoal. When it gets well heated, ore is let down through a hole at the top about 7 inches square, one small basketful at a time weighing from 5 to 7 seers. Some 25 to 30 such basketsful (or $3\frac{1}{2}$ to $4\frac{1}{2}$ maunds) of ore are consumed by a furnace in one day.

The produce of the furnace is a steely iron, known as *kheri*,[1] which is used for tipping implements of various kinds such as hatchet-heads, ploughshares, &c. As suggested by Mr. Mallet, there can be no doubt that the quality of the iron is due to the presence of manganese in the ore.

The spongy mass of *kheri* which comes out of the furnace is partially mixed up with slags. When cooled, it is beaten down with a heavy hammer, and broken into small blocks and fragments, the slags separating out in the process. The daily outturn of a furnace averages 24 seers of *cleaned kheri*.

The selling price varies. At the furnace it averages R10 per *gond* (= 24 *paseris*, or 3 maunds and 24 seers), or about 14 seers per rupee. At Sihora the price, according to my information, was 8 seers per rupee.

The working expenses of a furnace per month may be estimated as follows:—

	R	*a.*
Digging, dressing and carriage of ore at 2 annas per day (the Gogra rate)	3	12
Charcoal at 8 annas per day	15	0
Two bellowsmen (6 annas per day)	11	4
Duty on wood burned for charcoal	4	0
Royalty on ores	1	6
On account of bellows, &c.	1	0
Total	36	6

The monthly outturn averages 30 × 24 seers = 18 maunds. At R10 per *gond* of $3\frac{1}{2}$ maunds, the value of the outturn would be about R51-6. This leaves a fair margin for profit.

If the Umaria coal be found suitable, there is very good prospect for a steel manufactory on a large scale in the Lora hill area; and Khatola, where there is a railway station, appears to me to be best suited for the purpose. There is very rich manganiferous iron-ore close by (see p. 75); and the Hirun, probably the largest river in the northern portion of the Jabalpur district, flows past it.

[1] According to Mr. McMinn (*Central Indian News*, September, 1886), *Kheri* contains "80 per cent. of steel worth £45 per ton. It costs now in Jabalpur under £6 per ton."

NOTE (B).

The following statistics compiled from Phillips' "Treatise on Ore Deposit" and R. Hunt's "British Mining," may be found useful in forming an estimate of the value of the Jabalpur ores. The Manganese ores include *pyrolusite, manganite, psilomelane*, &c.:—

YEAR.	Quantity of manganese-ores.	Value.
I.—THE UNITED KINGDOM—	Tons.	£
1. Production of the mines in Cornwall, Devonshire, &c.		
1880	2,839	5,601
1881	2,884	6,441
1882	1,548	3,907
2. Imports.		
1880	16,085	67,070
1881	18,748	71,140
1882	29,760	102,267
II.—FRANCE, 1880	9,652	21,309
III.—THE GERMAN EMPIRE, 1881	13,642	23,534
IV.—ITALY, 1880.	6,505	8,575
V.—SPAIN, 1882	5,668	9,115
VI.—THE UNITED STATES, 1882.	3,500	10,500

"The Carboniferous Glacial Period," *by* Oberbergrath Prof. DR. W. WAAGEN.[1] *Translated by* R. BRUCE FOOTE, F.G.S., *Superintendent, Geological Survey of India.* (With one plate.)

Since the time when Agassiz and others entered upon a close study of glaciers, and it became practicable to recognize deposits formed by ice, even where the forming agency, the ice itself, had long disappeared, perfectly new vistas have opened to geological enquiry, and it has become possible to look back into the climatic conditions of periods which had long preceded historical tradition, and which till then had been regarded as separated by a great gulf from the present development of things. Studies in this direction, however, extended in the first place only to the glacial formations of the quarternary period, partly because the ice-formed deposits

[1] Jahrbuch der K. K. Geol. Reichsanstalt, 1887, 37, Band. 2, Heft. (W. Waagen).

belonging to this period are generally rather superficial in position, cover a comparatively large area, and play thus a more or less important part in the geological composition of many regions; partly also because, for obvious reasons, organic remains are pretty generally absent from glacial formations, and thus the age of such formations as do not belong to the quarternary period is generally extremely difficult to determine.

In spite of this, many voices have already been raised of those who believed they could demonstrate the action of ice in formations older than the quarternary; and there is hardly one of the greater epochs later than the Cambrian in which such formations have not been indicated: indeed, James Croll held that he could prove that each of the greater epochs in the history of the earth must consist of a series of glacial and interglacial periods. In this he deals very liberally with millions of years.

These voices have, however, hitherto died away with rather slight notice, because the whole body of geological facts would not fit in kindly with the theory, and because the facts, and specially those observed in the British islands, appeared on the one hand always as local phenomena only, while on the other hand, an unquestionably glacial character of these formations could not be absolutely proved. As time went on facts increased and proofs accumulated: and to-day it is hardly feasible any longer to wrap oneself in dissentient silence in opposition to the question whether glacial appearances are not traceable in prequarternary times; for the fact of the existence of glacial deposits is pretty generally admitted, although one could not begin to do much in general with this fact, a close determination of the age of these glacial formations being subject to very special difficulties.

It is one of the incontestably great merits of the Geological Survey of India to have advanced this "Glacial" question into the foreground, and to have published numerous facts tending towards its solution. The first case which was established by these studies, and which was one of great weight, was the fact that it appeared thus to be proven that the glacial beds in formations older than the quarternary are not merely local phenomena such as are found only in certain localities in England, but are really widespread and extending over great parts of the earth.

The oldest observations of the kind concerned India; where, in the year 1856, the so-called Talchir conglomerates were discovered, which were at the time pronounced by W. T. Blanford to be glacial. The definitive proofs of this were, however, only obtained in 1872 by Thomas Oldham and Fedden, who jointly excavated in the valley of the Godavari numerous scratched blocks of these beds, and also found the underlying formation, a hard Vindhyan limestone, to be scored with innumerable deep parallel scratches. A large granite block then found is exhibited in the Indian Museum in Calcutta, and forbids any doubt as to its having been tooled by ice.[1]

Another region in which conglomerates of peculiar character had long been known is South Africa. This formation was for a long while held to be of volcanic origin, till at last Sutherland[2] recognized the glacial origin of these block deposits

[1] Mem. Geol. Surv. Ind., Vol. IX, Part 2, p. 30. (Mr. Fedden made the original find. W. K.—*Ed.*)

[2] Quart. Journ. Geol. Soc. Lond., Vol. XXVI, p. 514.

also. Our countryman Griesbach, who knew these deposits from personal inspection in South Africa, was, when he came to India, surprised at the similarity which the Indian Talchir conglomerates show to the South African conglomerates, and did not hesitate to bring the two formations into correlation.

A third region in which glacial deposits in older formations were indicated was Australia. Before all others, it was the so-called Bacchus-marsh sandstone that was recognized as glacial, while the Hawksbury beds also appeared to have come into existence under glacial influences.

In all these three regions the glacial deposits appear in connection with coal seams, or sandstones containing a rich flora. This flora was by the majority of, and the best, palæophytologists regarded as Mesozoic; but the stratigraphical relations in India, and yet more especially in Australia, distinctly demanded that these formations should be reckoned in the Palæozoic rock series.

An irresolvable contradiction was thus created, which called forth a division of minds. Endless controversies were held in favour of one or other view: and the importance of the occurrence of glacial formations in these beds receded into the back ground, just because the exact age of the whole series of beds could not be determined with certainty. I will now endeavour to give a picture of the relative conditions for German readers, but in so doing cannot avoid repeating much that has already been variously discussed in German periodicals.

I.—INDIA.

The fundamental studies of these formations were published in 1856 by W. T. Blanford; and later on the whole series of beds received from H. B. Medlicott the name of "The Gondwana System."

Comprehensive data on this subject were given by W. T. Blanford in the *Manual of the Geology of India*, and more lately in his Address to the British Association at Montreal. His brother, H. F. Blanford, also gave a very good review of the subject, as then known, in his essay "*On the* Age *and* Correlations *of the* Plant-bearing Series *of* India, *and the former* Existence *of an* Indo-oceanic Continent" (Quart. Jour. Geol. Soc. London, Vol. XXXI, p. 519, 1875). The organic remains were worked out by Feistmantel.

It is difficult to treat the subject afresh since it has been so largely and so well written on. In particular it appears to me hardly possible to excel, or even to attain to, the masterly representation of the conditions given by W. T. Blanford in his Montreal Address: it will therefore be the wisest plan to let the first founder and zealous promoter of the whole question also speak on it in this place. I shall content myself therefore by giving here (in translation) the respective passages in Blanford's Address, and only making such additions to it as appear desirable for the benefit of German readers.

"*Gondwana System of India.*—In the peninsula of India there is a remarkable deficiency of marine formations. Except in the neighbourhood of the coast or of the Indus Valley there is, with one exception (some cretaceous rocks in the Nerbudda Valley), not a single marine deposit known south of the great Gangetic plain. But in Bengal and Central India, over extensive tracts of country, a great sequence of fresh-water beds, probably of fluviatile origin, is found, to which the name of

Gondwana system has been applied. The uppermost beds of this system, in Cutch to the westward, and near the mouth of the Godavari to the eastward, are interstratified with marine beds containing fossils of the highest Jurassic (Portlandian and Tithonian) types.[1]

"The Gondwana system is a true system in the sense that all the series comprised are closely connected with each other by both biological and physical characters, but it represents in all probability a much longer period of geological time than do any of the typical European systems. The highest members, as already stated, are interstratified with marine beds containing uppermost Jurassic fossils. The age of the lowest members is less definitely determined, and has been by different writers classed in various series from middle carboniferous to middle Jurassic. The Gondwana beds from top to bottom are of unusual interest on account of the extraordinary conflict of palæontological evidence that they present.

"The subdivisions of the Gondwana system are numerous, and in the upper portions especially the series and stages are different in almost every tract where the rocks are found. The following are the sub-divisions of most importance on account of their fauna and flora, or of their geological relations :—

Upper Gondwana ...	Cutch and Jabalpur.	
	Kota Maleri.	
	Râjmahâl.	
Lower Gondwana ...	Panchet.	
	Damuda ...	Ranigunj and Kámthi.
		Barákár.
	Karharbári.	
	Tálchir.	

"The upper Gondwanas, where best developed, attain a thickness of 11,000 feet and the lower of 13,000 feet.

"The Talchir and Barakar sub-divisions are far more generally present than any of the others.

"*Tálchir.*—The Tálchir beds consist of fine silty shales and fine soft sandstone. Very few fossils have been found in them, and these few recur almost without exception in the Karharbári stage. The Talchirs are principally remarkable for the frequent occurrence of large boulders, chiefly of metamorphic rocks. These boulders are sometimes of great size, 6 feet or more across, 3 to 4 feet being a common diameter; all are rounded, and they are generally embedded in fine silt."

These boulder beds are very widely distributed in Bengal and Central India, and boulders whose surfaces are marked with numerous parallel scratches are by no means uncommon. They form generally the base of the whole coal and plant-bearing series, and rest very often unconformably on older rocks. It has already been mentioned that when the basement is freshly exposed, the surface is scored with distinct parallel striæ. The thickness is often very great, but naturally changes within short distances. The glacial origin of these boulder deposits is clear beyond all cavil.

Griesbach[2] has given a very instructive chromo-lithographed sketch of such

[1] This and the following quoted passages are all from Mr. Blanford's address as President of the Geological Section of the British Association, at Montreal, 1884: also published in Records, G. S. I., XVIII, p. 32 *et. seq.*—W. K.

[2] Mem. Geol. Surv. Ind., 1880, Vol. XV, pt. 2, pl. 2.

a bed, which shows most convincingly the irregular distribution of the boulders in the fine greyish-green sandy clay. The soft sandstone and shales occur generally only above the boulder clay. A few plant remains occur in the shales, and from among them Feistmantel determined the following species :—

Schizoneura, sp.
Gangamopteris cyclopteroides, Fstm.
,, angustifolia, McCoy.
Glossopteris, sp.
Nœggerathiopsis hislopi, Bunb., sp.

Of these *Gangamopteris cyclopteroides* is the predominant form, and *G. angustifolia* is identical with a form that was originally described from the Bacchus-marsh sandstone. This Australian formation also shows similar characters.

"*Karharbári.*—The Karharbári beds are found in but few localities." They stand in the closest relation to the Tálchir beds, and can hardly be regarded as a separate division. Here and there they contain coal-seams, and are then often rather rich in plant remains.

Up to the present Feistmantel has described the following species from these beds :—

Schizoneura cf. meriani, Schimp.
Vertebraria indica, Royle.
Neuropteris valida, Fstm.
Gangamopteris cyclopteroides, Fstm. in many varieties.
,, buriadica, Fstm.
,, major, Fstm.
,, angustifolia, McCoy.
Glossopteris communis, Fstm.
,, decipiens, Fstm.
Sagenopteris stoliczkana, Fstm.
Glossozamites stoliczkanus, Fstm.
Nœggerathiopsis hislopi, Bunb, sp.
Euryphyllum whittianum, Fstm.
Voltzia heterophylla, Brogn.
Albertia, sp.
Samaropsis cf. parvula, Heer.
Carpolithes milleri, Fstm.

"The most abundant form is a *Gangamopteris*. The *Voltzia* (*V. heterophylla*) is a characteristic Lower Triassic (Bunter) form in Europe. The *Neuropteris* and *Albertia* are also nearly related to the Lower Triassic forms. The species of *Gangamopteris, Glossopteris, Vertebraria* and *Nœggerathiopsis* are allied to forms found in Australian strata." I myself had occasion to study the Karharbári beds more closely during an excursion which I made in the summer of 1871 with Dr. Stoliczka. Mr. Heine, a German, was then manager of the collieries at Karharbári. He had just then bared the coal seams in a couple of open workings, and invited us to inspect these workings. We found two seams exposed to daylight (at small depths) in terrace-like steps by the clearing away of the overlying sandstone mass, so that only a thin layer of shale covered the coal itself. The exposed surface measured at the lowest estimate many square metres, and was covered with well-preserved plant remains,—a real joy to the eye of a palæontologist. Unluckily the harvest was not so great as we had expected. It was the hot season; and the shales had been exposed for

several days to the glowing sun and to the furnace blasts of the hot winds, and the rock was in consequence so cracked that it crumbled away under the lightest touch of chisel or hammer. If Mr. Heine had not previously preserved specimens for us, we must have departed empty-handed. The specimens then procured formed the chief basis for Feistmantel's descriptions. Only few geological observations could then be made because of the terrible heat. The beds are all nearly horizon tal, but their relations to the not distant beds of the Damuda coal-basin could not be accurately observed because vast tropical forests cover a great part of that region.

"*Damuda.*—The Damuda series consists of sandstones and shales with coal beds; the floras of the different sub-divisions present but few differences," * * * Feistmantel has described the following species out of the Damuda series:—

Schizoneura gondwanensis, Fstm.
Phyllotheca Indica, Bunb.
" *robusta, Fstm.*
Trizygia speciosa, Royle.
Vertebraria indica, Royle.
Cyathea cf. tchihatcheffi, Schmalh.
Sphenopteris polymorpha, Fstm.
Dicksonia hughesi, Fstm.
Alethopteris whitbyensis, Goepp.
" *lindleyana, Royle.*
" *phegopteroides, Fstm.*
Pecopteris affinis, McCl.
Merianopteris major, Fstm.
Macrotæniopteris danæoides, Royle.
" *feddeni, Fstm.*
Palæovittaria kurzi, Fstm.
Angiopteridium cf. m'clellandi, Oldh.
" *infractum, Fstm.*
Glossopteris communis, Fstm.
" *intermittens, Fstm.*
" *stricta, Bunb.*
" *musafolia, Bunb.*
" *indica, Schimp.*
" *browniana, Bgt.*
" *intermedia, Fstm.*
" *retifera, Fstm.*
" *conspicua, Fstm.*
" *ingens, Fstm.*
" *divergens, Fstm.*
" *damudica, Fstm.*
" *angustifolia, Bgt.*
" *leptoneura, Bunb.*
" *formosa, Fstm.*
" *orbicularis, Fstm.*
Gangamopteris anthrophyoides, Fstm.
" *whittiana, Fstm.*
" *hughesi, Fstm.*
" *cyclopteroides, Fstm.*
Belemnopteris wood-masoni, Fstm.
Anthrophyopsis, sp.
Dictyopteridium, sp.

Sagenopteris logifolia, Fstm.
" *polyphylla, Fstm.*
Actinopteris bengalensis, Fstm.
Pterophyllum burdwanense, M'Cl., sp.
Anomozamites, sp.
Naggerathiopsis hislopi, Fstm.
Rhipidopsis densinervis, Fstm.
Voltzia heterophylla, Brgt.
Samaropsis cf. parvula, Heer.

Besides these a few animal remains were found, *viz.*—

Estheria mangaliensis, Jones.
Brachyops laticeps, Owen.
Gondwanosaurus bijorensis, Lyd.

Of these remains there is nothing more to be said than that *Brachyops* is more or less nearly related, while *Gondwanosaurus* approaches very closely to *Archegosaurus*.

"The most abundant of the above-named fossils are *Glossopteris* and *Vertebraria.* With the exception of *Naggerathiopsis*, all the cycads and conifers are of excessive rarity. More than one-half of the species known are ferns with simple undivided fronds and anastomosing venation."

"For many years European palæontologists generally classed this flora as Jurassic. This was the view accepted by De Zigno and Schimper and, though with more hesitation, by Bunbury. The species of *Phyllotheca*, *Alethopteris* (or *Pecopteris*), and *Glossopteris* (allied to *Sagenopteris*) were considered to exhibit marked Jurassic affinities. It was generally admitted that the Damuda flora resembles that of the Australian coal-measures * * * * more than it does that from any known European formation; but the Australian plants were also classed as Jurassic. There is no reason for supposing that the more recent discoveries of Damuda plants would have modified this view; the identification of such forms as true *Sagenopteris* and the cycads *Pterophyllum* and *Anomozamites* would assuredly have been held to confirm the Jurassic age of the beds. So far as European fossil plants are concerned, the Damuda flora resembles that of the Middle or Lower Jurassics more than any other.

"One form, it is true, the *Schizoneura*, is closely allied to *S. paradoxa* from the Bunter or lower Trias of Europe. Other plants have Rhætic affinities. But the connections with the Triassic flora do not seem nearly equal to those shown with Jurassic plants, and the reason that the Damuda flora has been classed as probably Triassic must be sought in the impossibility of considering it newer, if the next overlying stage is classed as Upper Trias or Rhætic, and in the close affinity with the underlying Karharbári beds, which contain several Lower Triassic types.

"*Panchet.*—The uppermost series of the Lower Gondwanas consists chiefly of sandstones and fossils are rare. The most interesting are remains of *Reptilia* and *Amphibia.*" The following is a list of the faunna and flora:—

Epicampodon indicus, Huxley, sp.
Dicynodon orientalis, Huxl.
Pachygonia incurvata, Huxl.
Gonioglyptus longirostris, Huxl.
" *huxleyi, Lyd.*

Glyptognathus fragilis, Lyd.
Estheria, sp.
Schizoneura gondwanensis, Fstm.
Vertebraria indica, Royle.
Pecopteris concinna, Presl.
Cyclopteris pachyrrhachis, Goepp.
Thinnfeldia cf. *odontopteroides*, Morr., sp.
Oleandridium cf. *stenoneuron*, Schenk.
Glossopteris communis, Fstm.
" *indica*, Schimp.
" *damudica*, Fstm.
" *angustifolia*, Bgt.
Samaropsis cf. *parvula*, Heer.

The *Schizoneura*, the *Vertebraria* and the various species of *Glossopteris* are identical with those found in the Damuda beds. Besides them are several species identical with those of the Rhætic beds of Europe, and two others have their nearest relatives in these beds, and thus perhaps the whole flora of the Panchets may be regarded as Rhætic, or at least as Triassic.

" All the genera of *Labyrinthodonts* named are peculiar, their nearest European allies are chiefly Triassic. *Dicynodontia* are only known with certainty from India and South Africa, but some forms believed to be nearly allied have been described from the Ural Mountains. These fossils were obtained from rocks now referred to the Permian.

" *Upper Gondwanas.*—The different series of the lower Gondwanas are found in the same area resting one upon the other, so that the sequence is determined geologically. This is not the case with the upper Gondwana groups; their most fossiliferous representatives are found in different parts of the country, and the relations to each other are mainly inferred from palæobotanical data. Although, therefore, it is probable that the Rájmahál are older than the Cutch and Jabalpur beds, and that the Kota-Maleri strata are of intermediate age, it is quite possible that two or more of these series may have been contemporaneously formed in regions with a different flora.

" *Rájmahál.*—The comparatively rich flora of the lowest upper Gondwana series is contained in beds interstratified with basaltic lava-flows of the fissure-eruption type." The following are the genera of plants found :—

Equisetum rajmahalense, Schimp.
Gleichenia bindrabunensis, Schimp.
Danæopsis rajmahalensis, Fstm.
Dicksonia bindrabunensis, Fstm.
Hymenophyllites bunburyanus, Oldh.
Pecopteris lobata, Oldh.
Sphenopteris hislopi, Oldh.
" *membranosa*, Fstm.
Cyclopteris oldhami, Fstm.
Thinnfeldia indica, Fstm.
Asplenites macrocarpus, Oldh.
Macrotæniopteris crassinervis, Fstm.
" *lata*, Oldh.
" *morrisi*, Oldh.
" *ovata*, Schimp.

Angiopteridium spathulatum, M'Cl., sp.
„ *m'clellandi, Oldh., sp.*
„ *ensis, Oldh., sp.*
Rhizomopteris balli, Fstm.
Lycopodites gracilis, Fstm.
Pterophyllum carterianum, Oldh.
„ *crassum, Morr.*
„ *distans, Morr.*
„ *kingianum, Fstm.*
„ *medlicottianum, Oldh.*
„ *propinquum Goepp.*
„ *rajmahalense, Morr.*
Anomozamites fissus, Fstm.
„ *morrisianus, Oldh., sp.*
„ *princeps, Oldh, sp.*
Zamites proximus, Fstm.
Ptilophyllum tenerrimum, Fstm.
Otozamites abbreviatus, Fstm.
„ *bengalensis, Schimp.*
„ *oldhami, Fstm.*
Dictyozamites indicus, Fstm.
Cycadites confertus, Oldh.
„ *rajmaholensis Oldh.*
Williamsonia cf. gigas, Carr.
„ *microps, Fstm.*
Cycardinocarpus rajmahalensis, Fstm.
Palissya conferta, Oldh., sp.
„ *indica, Oldh., sp.*
Cheirolepis cf. münsteri, Schimp.
Araucarites macropterus, Fstm.
Cunninghamites, sp.
Echinostrobus rajmahalensis, Fstm.

"The marked change from the Lower Gondwana floras is visible at a glance; not a single species is common to both, most of the genera are distinct, and the difference is even greater when the commonest plants are compared. In the Lower Gondwanas the prevalent forms are *Equisetaceæ* and ferns of the *Glossopteris* type, whilst in the Rájmahál flora cycads are by far more abundant than any other plants. The whole assemblage, moreover, is more nearly allied than are any of those in the Lower Gondwana beds to European mesozoic floras.

"Of the Rájmahál plants about fifteen are allied to Rhætic European forms, three to Liassic or lower Jurassic (two of these having also Rhætic affinities), and six to Middle Jurassic (two having Rhætic relations as well). The flora must therefore, as a whole on purely palæontological grounds, be classed as Rhætic."

Although Professor Feistmantel wishes to have the Rájmahál beds also regarded as Liassic, he cannot adduce any cogent reasons for it; though it is not meant to imply hereby that these beds might not in part be contemporaneous with liassic formations.

"*Kota Maleri.*—The deposits belonging to this series are found in the Godavari valley at a considerable distance from the Rájmahál hills in Bengal, the locality for the Rájmahál flora. Both Rájmahál and Kota-Maleri beds overlie rocks of the Damuda series. It is not quite clear whether the Kota beds, which contain fish, insects, and crustaceans, and the Maleri beds, in which remains of fish, reptiles, and plants are found, are interstratified, or whether the Kota beds overlie those of

Maleri. That the two are closely connected is generally admitted." From the Maleri beds the following remains have been recorded :—

Hyperodapedon Huxleyi, Lyd.
Parasuchus hislopi, Lyd.
Pachygonia cf. incurvata, Huxl.
Scutæ of undetermined Labyrinthodonta.
Ceratodus virapa, Oldh.
" hunterianus, Oldh.
" hislopianus, Oldh.
Lepidotus pachylepis, Eg.
" calcaratus, Eg.
" deccanensis, Sykes, Eg.
" longiceps, Eg.
" breviceps, Eg.
Tetragonolepis oldhami, Eg.
" analis, Eg.
" urgosus, Eg.
Dapedius egertoni, Sykes.
Estheria kotahensis, Jones.
Candona kotahensis, Jones.
Angiopteridium spathulatum, M'Cl.
Ptilophyllum acutifolium, Morr.
Cycadites, sp.
Palissya conferta, Oldh.
" jabalpurensis, Fstm.
" indica, Oldh.
Chirolepis, sp.
Araucarites cutchensis, Fstm.

In South Rewa remains of *Belodon* and (?) *Thecodontosaurus* were found in beds of probably similar age, while from Denwa a *Mastodonsaurus* has been described.

"The fish are Liassic forms." The reptilia of the Maleri beds are on the other hand triassic. "*Ceratodus* is chiefly triassic." But it occurs also in the Permian, and Jurassic. The plants show relations with both the Rájmahál and Jabalpur floras; and as the palæontological relations to beds in the same country are considered far higher in importance than those to deposits in distant regions, the Kota Maleri beds are classed as intermediate between the Rájmahál and Jabalpur epochs.

"*Cutch* and *Jabalpur.*—The Jabalpur beds are found in Central India to the south of the Nerbudda valley, and form the highest true Gondwana beds. The Cutch beds, as already mentioned, are found interstratified with marine deposits of uppermost Jurassic age far to the westward, a little east of the mouths of the river Indus. The similarity of the plant remains in the two series has caused them to be classed together, but it is not certain that they are really of contemporaneous origin." Similar beds have also been found in South India on the east coast near the mouth of the Godavari, but their flora is already somewhat differentiated.

The following species have been determined up to date out of the Jabalpur beds :—

Sphenopteris cf. arguta, L. and H.
Dicksonia, sp.

Alethopteris lobifolia, *Schimp.*
" *medlicottiana Oldh.*
" *whitbyensis*, *Göpp.*
Macrotæniopteris, *sp.*
Glossopteris cf. communis.
Sagenopteris, *sp.*
Podozamites lanceolatus, *L. and H.*
" *spathulatus*, *Fstm.*
" *hacketi*, *Fstm.*
Otozamites hislopi, *Oldh.*
" *gracilis*, *Schimp.*
" *distans*, *Fstm.*
" *angustatus*, *Fstm.*
Ptilophylium acutifolium.
" *cutchense*, *Morr.*
Pterophyllum nerbuddiacum, *Fstm.*
Williamsonia cf. gigas, *Carr.*
Cycadites cf. graminens, *Heer.*
Palissya indica, *Oldh.*
" *jabalpurensis*, *Fstm.*
Araucarites cutchensis, *Fstm*
Brachyphyllum mamillare, *L. and H*
Echinostrobus expansus, *Schimp.*
Taxites tenerrimus, *Fstm.*
Ginko lobata, *Fstm.*
Czekanowskia, *sp.*
Phœnicopsis, *sp.*

Of these plants six are identical with species from the lower Oolite of England, and a few others are nearly related to the same. The occurrence of *Glossopteris* and *Sagenopteris* gives a somewhat archaic aspect to the whole flora. Besides the above are four species, which are identical with four others from the Rájmahál beds.

The following fossil plants were procured in the peninsula of Cutch:—

Chondrites dichotomus, *Morr.*
Oléandridium vittatum, *Brgt.*
Tæniopteris densinervis, *Fstm.*
Alethopteris whitbyensis, *Brgt.*
Pecopteris tenera, *Fstm.*
Pachypteris specifica, *Fstm.*
" *brevipinnata*, *Fstm.*
Actinopteris, *sp.*
Ptilophyllum cutchense, *Morr.*
" *acutifolium*, *Morr.*
" *brachyphyllum*, *Fstm.*
Otozamites contiguus, *Fstm.*
" *imbricatus*, *Fstm.*
" *cf. goldiæi*, *Brgt.*
Cycadites cutchensis, *Fstm.*
Williamsonia blanfordi, *Fstm.*
Cycadolepis pilosa, *Fstm.*
Palissya boojoorensis, *Fstm.*
Pachyphyllum divaricatum, *Bunb.*
Echinostrobus expansus, *Schimp.*

The species marked with asterisks are identical with species from the Jabalpur beds, and it is possible also that one of the unnamed species of *Palissya* may also have to be regarded as identical. Seven are, according to Feistmantel, identical with species from the Lower Oolite of Yorkshire, and further, three very closely related; but probably the identity of only the four is really established.

The plant-bearing beds are in their lower parts interbedded with marine deposits, which represent the upper division of a long series of Jurassic beds, within the limits of which all the zones of the Kelloway, Oxford, and Kimmeridge groups are represented.

The upper bed in particular has yielded the following cephalopoda:—

Haploceras cf. tomephorum, Zitt.
Aspidoceras wynnei, Waagen.
Perisphinctes cf. suprajurensis, Orb.
,, *bleicheri, Lor.*
,, *occultefurcatus, Waagen.*
,, *eudichotomus, Zitt.*

All these are Portland-Tithonian types. The plant-bearing beds are overlaid by Aptian deposits.

This concludes the series of the several divisions of the Gondwana system. To enter further into the controversies as to the real age of these uppermost plant beds would take me beyond the scope of the present work.

The final result of the whole presentment appears to be that there exists in India a great rock system which includes at its base glacial deposits, and which, according to the fossil plants it contains, has been regarded as belonging to the Mesozoic era. But doubts as to this conclusion were advanced because it appeared probable on geological grounds, that the lower divisions of the system were of greater antiquity. W. T. Blanford has sought to prove by arduous and spirited deductions that the Tálchirs and Damudas answer to the Permian of Europe, and in so doing came very near to the truth, but he had no positive proofs; and thus the palæoplytologists were still at liberty to abide by their views, and to regard the type of the floras as determinant of the age of the formations.

Blanford had in his deductions already partially leant upon the presence of the glacial formations.

II.—South Africa.

In the matter of geological details in Africa we are unfortunately much less well-informed than could be desired, or than we are with regard to India. Roughly sketched, the geological structure of South Africa may be represented as a vast sandstone region occupying the entire centre, the margins of which are framed by a broad belt of older formations, crystalline rocks, old slates, and Devonian beds. On the outside edge along the coast small tracts of the central sandstone formation re-appear in isolated patches; here, however, the sandstones are interbedded with marine formations, which are entirely wanting in the central area.

The whole structure itself reminds one strongly of the conditions pertaining in India; and the resemblance becomes yet more striking the more one goes into detail.

It is the central sandstone formation, the so-called Karoo formation, which is

especially interesting. This formation spreads itself throughout the north part of the Cape Colony, the Orange Free State, Natal, the Transvaal, and the deserts lying further westward, and shows a series of sandstones and shales (interrupted here and there by eruptive rocks), which attains a maximum thickness of about 5,000 feet. The basis of the whole system is a rather varied one, as it for the most part rests unconformably on the older rocks.

Most frequently the basis consists of the so-called Table Mountain sandstones, whose age has been much disputed. They are generally regarded as Devonian, but in an essay which has just appeared, E. Cohen[1] has shown that they should preferably be reckoned to the Carboniferous system. They rest partly in unconformity on clay-slates of probably Silurian age, and partly conformably on the richly fossiliferous Devonian grey-wackes of the Bokkeveld. Other whitish or yellowish sandstones which appear on the Witteberg and Zuurberg, as also near Graham's Town, Winterhock[2] and other places, have yielded remains of *Lepidodendron*. At Tulbagh, in the Cape Colony, these beds contain coal, in which remains of *Calamites*, *Equisetum* and *Lepidodendron* are found.[3]

Overlying these formations unconformably comes the Karoo formation, which often rests directly on the Devonian grey-wackes.

The Karoo formation is reducible to a series of sub-formations, which may be represented as follows according to Wyley's full classification :—

	Stormberg beds	1,800′ thick.
	Beaufort beds	1,700′ „
	Koonap beds	1,500′ „
Ecca beds	Upper Ecca shales	1,200′ „
	Ecca conglomerate	500′—800′ thick.
	Lower Ecca shales	of no great thickness.

The lowest beds of the lower Ecca shales are said to be strongly contorted equally with the sandstones which are connected with them. They occur at the same places with the Carboniferous sandstones above referred to (Witteberg, Zuurberg, &c.) and are reported fossiliferous.

As all the other beds, both over and underlying, are nearly absolutely horizontal and undisturbed, the contorted character of these shales is remarkable. They occur, however, but in few places.

In general, the older deposits are overlaid by the *Ecca conglomerate*, a most remarkable rock, which for many years was regarded as eruptive and called a "trap breccia." Dr. Sutherland was the first who recognized the action of ice in the formation of these beds, but at the time his views met with much objection.[4]

Dr. Sutherland describes the deposit as composed of grey-blue clayey material, in which fragments of granite, gneiss, greenstone, and clay slate are imbedded. These fragments are of very various sizes from little grains of sand to huge blocks, 6 feet in diameter and weighing from 6 to 10 tons. These blocks are generally smoothed, as if they had been to a certain extent ground down in a clayey sediment, but they are not rounded like blocks which have been exposed to surf-

[1] E. Cohen, Neues Jahrb. f. Min. Geol. u. Pal. V. Beil-Band, 1887, p. 195.
[2] Wyley, Quart. Jour. Geol. Soc. Lond., XXIII, 1867, p. 173.
[3] Griesbach., Ibid, XXVII, 1881, p. 57.
[4] Quart Jour. Geol. Soc. Lond., 1870, Vol. XXVI, p. 514.

action. The fracture of the clayey matrix is not conchoidal; and, in general, the rock shows a certain tendency to obscure wavy bedding. In places the beds show distinct ripple marks. The thickness of this formation is very various, but in some places it attains as much as 1,200 feet.

These conglomerates rest, as a rule, unconformably on the Table Mountain sandstones, and at the surfaces of contact the sandstones are generally marked with deep grooves and scratchings "as if a heavy semi-plastic substance with included hard and angular fragments had moved across it;" a very drastic description of the effects of a moving ice-mass!

In an upward direction the conglomerates pass quite gradually into the next overlying group of beds.

Upper Ecca Shales.—These are generally dark-grey shales of very considerable thickness with but few intercalated sandstones. Locally they contain coal seams, and plant remains are reported not unfrequent, but up to the present only the genus *Glossopteris* has been cited.

Koonap beds.—Brown sandstone and shales, which latter, however, often show a greenish tint. Plant remains are common, particularly in the upper beds, but the plants have not yet been described.

Beaufort beds.—Dark red greenish or grey shales, with comparatively few sandstone deposits, but with all the more numerous reptile-remains. Fish teeth and plant impressions also occur there. The Karoo plant-remains, described by Tate, are said to have come out of these beds, but might just as well have been derived from the Koonap beds. The bed is unfortunately not sufficiently well known. The following species have been described:—

Glossopteris browniana, Bgt.
,, *sutherlandi, Tate.*
,, *(Dictyopteris ?) simplex, Tate.*
,, *(Rubidgea) mackayi, Tate.*
Phyllotheca sp.

At the first glance it is clear that these plants have a great resemblance to those of the Damuda beds. On the other hand, they are also nearly allied to similar species in Australia as will be clearly shown further on.

The fauna of the Beaufort beds is much richer than the flora. Up to the present only vertebrate remains have been found, a complete enumeration of which is given in Owen's Catalogue of the Fossil Reptilia of South Africa, contained in the British Museum.

Three groups in particular are represented—the Dicynodonta, the Theriodonta, and the Dinosauria. We have already seen that Dicynodonta occur in the Indian Panchet beds.

The Stormberg beds.—Thick sandstones of white or light red colour, with subordinate beds of shale and coal seams. Of plant-remains the following species have been described up to the present:—

Pecopteris (thinnfeldiä), Bgt.
,, *sutherlandi, Tate.*
Cyclopteris cuneata.
Tæniopteris daintreei.[1]

[1] Dunn, Report on the Stormberg Coalfield. Geol. Mag., 1879, p. 552.

All these are species which occur equally in the uppermost plant-bearing beds of Australia. Of animal remains the skull of a mammal has *imprimis* been described and received the name of *Tritylodon triglyphus*.[1]

Neumayr has shown that this specimen is remarkably near in its alliance to the genus *Triglyphus* of Fraas from the Rhætic bone bed of Würtemberg, and might possibly be, by some, regarded as generically identical.

If all the relations of the Stormberg beds to the extra-African formations be considered, it would appear that of the Indian rocks the Rájmahál and Jabalpur formations should first be reckoned as their equivalents.

The Uitenhage group.—In the interior, the Karoo system terminates with the Stormberg beds; but along the coast, from the southernmost point up to the neighbourhood of Natal and the Tugela river, appear marine beds alternating with plant-bearing beds, which are assigned partly to the Jurassic, partly to the middle and upper Cretaceous periods. The relations of these deposits to the Karoo system are obscure, and have up to the present not been worked out with sufficient care. But nevertheless the beds are of great interest. The cretaceous rocks described by Griesbach and Baily, and which agree most closely with those of South India, we may here conveniently neglect; but the Uitenhage group deserves our attention all the more.

The geological age of this group has been determined with considerable certainty by Neumayr's latest work on this subject,[2] and there can hardly be any doubt that the whole group must be regarded as Neocomian.

The most important fossils with reference to this conclusion, are :—

Olcostephanus atherstoni, Sharpe.
,, baini, Sharpe.
Crioceras spinosissimum, Hausm.
Hamites africanus, Tate.
Trigonia herzogi, Hausm.
,, ventricosa, Krauss.
,, conocardiiformis, Krauss.
Ptychomya implicata, Tate.

The occurrence of *Trigonia ventricosa* in the Indian Tithonian beds of Cutch can, in view of the occurrence of the Cephalopoda just named, hardly effect much change in the above conclusion, though it may indicate the necessity of being careful.

But besides the marine fossils, plant-remains occur also in these beds, and Tate has described the following species :—

Otozamites recta, Tate.
Podozamites morrisi, Tate.
Palæozamia rubidgei, Tate.
Peterophyllum africanum, Tate.
Pecopteris atherstonei, Tate.
,, rubidgei, Tate.
,, africana, Tate.
Asplenites lobata, Oldh.
Sphenopteris antipodum, Tate.
Cyclopteris jenkinsiana, Tate.
? Arthrotaxites indicus, Oldh.

[1] Bronns Jahrb., 1884, I., p. 279.

[2] E. Holub and M. Neumayr, Über einige Fossilien aus der Uitenhage—Formation in Süd-Africa. Denkschr. Kais. Akad. d. Wiss. Wien, Vol. XLIV.

Of these species two are identical with Rájmahál species from India. The others are allied partly to Rájmahál species and partly to Scarborough species. As a whole, the flora is considered as Jurassic.

The mere occurrence of *Trigonia ventricosa* in South Africa and India leads us to regard these Uitenhage beds as equivalent to the uppermost divisions of the Cutch Jurassics, the Umia beds, or the Cutch plant beds. The geological conditions are also agreeable to this. In Cutch the chief mass of the plant-beds follows the Tithonian beds, while in South Africa the plant-beds alternate with Neocomian deposits.

This is all that is known about South Africa. On the whole, there appears to be a pretty close agreement with India, but in the former region the conditions have been too little studied to admit of perfectly certain conclusions. It is highly desirable that a survey of South Africa on the Indian pattern should be established.

One uncertainty I must point out specially. According to the earlier writers it appears that the Ecca beds lie unconformably on the older formations, and that from this point a conformable succession of deposits occurs, but lately it has been asserted that they lie conformably on the older rocks, and that the unconformity appears first between the Eccas and Koonaps. As, however, the Carboniferous sandstones appear to occur only here and there, it is probable that in most places an unconformability exists also between the Eccas and the older formations.

III.—EASTERN AUSTRALIA.

Although the existence in Australia of coal seams with many fossils has long been known, the great geological features of the continent have been but little explored, and many questions which one would much like to have answered cannot be solved on the strength of the existing literature. This imperfect knowledge is due partly to the great difficulty of penetrating into the interior, but chiefly to the peculiar stratigraphical conditions of the Australian formations.

The greatest merit for the geological exploration of Australia was due to the late Reverend W. B. Clarke, and it is specially to the sub-divisions established by him for New South Wales, in the first place, that the formations of other districts must be referred.[1]

The Carboniferous formations of Australia must be of very great vertical thickness, but it is hard to make this out from what has been written about them. The succession is not everywhere the same, nor everywhere complete. Generally the carboniferous beds rest unconformably on older rocks (granite, porphyry, &c.), and the newer members often overlap the older. Silurian and Devonian formations are known (the latter limestones with many marine animal remains), but their relations to the carboniferous beds are very obscure. In the interior, and possibly representative of the more easterly marine formations, is a great deposit of yellow sandstones, which up to the present have only yielded *Lepidodendron* and a species

[1] Quite lately an entirely different scheme of formations in New South Wales has been propounded by Mr. T. W. E. David, in a paper read before the Geological Society of London, but his views were objected to in the discussion which followed the reading of the paper. But the carboniferous glacial formations are most minutely described in Mr. David's paper, and their geological horizon confirmed. Quart. Jour. Geol. Soc. Lon. Vol. XLIII, 1887, p. 190.

of *Cyclostigma*. These beds are generally regarded as Devonian. On these, Carboniferous beds are said to rest, here and there, in regular position, but as to this also there is no certainty.

The Carboniferous beds are arranged by Clarke as follows in downward succession :—

Wianamatta beds.
Hawksbury beds.
Newcastle beds.

Muree beds divided into { Upper marine beds. / Older coal seams. / Lower marine beds. }

I shall try to describe each of these divisions rather fully.

Muree beds.—This is, for our present purpose, the more important division ; because on the one hand, beds that have been formed under glacial co-operation occur here largely developed, while on the other hand, some of the deposits contain marine fossils which enable one to determine the age of the beds. There is certainly much here that has not yet been sufficiently determined, but some conclusions may be safely drawn from the facts now known.

As stated above, Clarke divides this series into " Upper marine beds," " Older coal seams," and " Lower marine beds." The whole succession of beds is probably best exposed and most accessible at Stony Creek and near Greta, where the Great Northern Railway cuts through these beds and exposes them in several cuttings, and where several bore holes and pits have penetrated the series.

According to R. D. Oldham, the series exposed both at Stony Creek and Greta is one and the same; the wings of a great anticlinal having been pierced. Clarke gives full sections of the coal pits at both places, and from these it is clear that the main mass of the beds there exposed consists of coarse conglomerate and boulder deposits, which include subordinate sandstones and shales, and near the base several coal seams. Below these seams there occur, according to Oldham, other marine conglomerates. Nearly all the beds exposed in these sections are fossiliferous ; and marine animal remains as well as plants are contained here and there in the same bed.

The animal remains are all of Carboniferous type, and were fully described by L. G. de Koninck in his " Recherches sur les fossiles paléozoiques de la nouvelle Galle du Sud." In this work 74 species out of 176 have been identified with European carboniferous limestone forms. The most important are :—

* *Productus cora, Orb.*
* „ *semireticulatus, Mart.*
* „ *flemingi, Sow.*
„ *undatus, Defr.*
* „ *punctatus, Mart.*
„ *fimbriatus, Sow.*
* „ *labriculus, Mart.*
Strophomena analoga, Phill.
* *Orthothetes crenistria, Phill.*
* *Orthis resupinata, Mart.*
„ *michelini, Sow.*
* *Rhynch. pleurodon, Phill.*

* *Athyris planosulcata*, Phill.
* *Spirifer lineatus*, Mart.
* " *glaber*, Mart.
* " *pinguis*, Sow.
" *convolutus*, Phill.
" *triangularis*, Mart.
" *bisulcatus*, Sow.
* *Spiriferina cristata*, Schl.
" *insculpta*, Phill.
? *Cyrtina septosa*, Phill.
* *Terebratula sacculus*, Mart.

" With regard to this list it should be specially remarked that the species against which an asterisk has been placed are distributed through the whole Carboniferous formation, and cannot therefore be used for determining the horizon more closely. Of the remaining species, M. de Koninck will probably not be able, even now after an interval of ten years, to identify several with their representative European forms, since he has in his splendid work on the Belgian Carboniferous Limestone, admitted so much more accurate and limited an idea of species. It must be noted, however, that even with the wide meaning M. de Koninck then gave to the idea of species, no form could be identified with *Productus giganteus*, so that this whole group of forms is certainly not represented. It is important to lay stress on this, as *Productus giganteus* in particular is one of the most characteristic species of the lower and middle carboniferous series, while it is distinctly wanting in the upper coal-measures. But *per contra*, there appear in Australia numerous forms which are nearly related to forms in the Permian formations of the Salt-Range (India), *e.g.*, species of the genera *Warthia*, *Atomodesma* (*Aphanaia*) and *Martiniopsis*. All these particulars cause the general character of this marine fauna to appear as pointing with great probability to an age corresponding with that of the upper coal-measures of Europe and America.

We shall see in the course of this sketch that in Australia itself other grounds are to be found for this age determination.

According to Dr. Feistmantel's list,[1] the following remains were discovered in these beds :—

Phyllotheca, sp.
Glossopteris browniana, Bgt.
" " *var. præcussor*, Fstm.
" *primæva*, Fstm.
" *clarkei*, Fstm.
" *elegans*, Fstm.
Næggerathiopsis prisca, Fstm.
Annularia anstralis, Fstm.

Although they mostly show mesozoic characters, these plants are unquestionably found occurring together with the animal remains above enumerated."

Very important in every respect is the information furnished by R. D. Oldham, that the greatest part of the beds containing the above-named plants and animal

[1] Notes on the fossil Flora of Eastern Australia and Tasmania. Trans. Roy. Soc., New South Wales, 1860.

remains have been formed by the action of ice. Mr. Oldham visited Greta and Stony Creek personally, and described[1] the beds thus:—

"Blocks of slate, quartzite and crystalline rocks, for the most part sub-angular, are found scattered through a matrix of fine sand or shale, and these latter beds contain delicate *Fenestellæ* and bivalve shells with the valves still united, showing that they had lived, died and been tranquilly preserved where they are now found, and proving, as conclusively as the matrix in which they are preserved, that they could never have been exposed to any current of sufficient force and rapidity to transport the blocks of stone now found lying side by side with them. These included fragments of rock are of all sizes, from a few inches to several feet in diameter, the largest I saw being about 4 feet across in every direction as exposed in the cutting, and of unknown size in the third dimension; but I was informed by Mr. Wilkinson that in these same beds he has seen boulders of slate, &c., whose dimensions may be measured in yards.

"It is impossible to account for these features except by the action of ice floating in large masses, and I had the good fortune to discover, in the Railway cutting near Branxton, a fragment beautifully smoothed and striated in the manner characteristic of glacier action, besides at least two others which showed the same feature, though obscurely. This seems to show that the ice was of the nature of icebergs broken off from a glacier which descended to the sea-level."

Such are the conditions which are found in the sections along the railway west of Newcastle, and chiefly near Greta and in the Stony Creek; but this does not exhaust all that has to be said about the Muree beds.

In other parts of the country as near Stroud, Arowa, Port Stephens and Smith's Creek, there is yet another flora which does not occur at Greta, &c., but must certainly be older than that above described. This older flora consists, according to Feistmantel, of the following species:—

Calamites radiatus, Brgt
Sphenophyllum, sp.
Rhacopteris inaequilatera, Göpp
,, *intermedia*, Fstm.
,, *cf. rœmeri*, Fstm.
,, *septentrionalis*, Fstm.
Archaeopteris wilkinsoni, Fstm.
Cyclostigma australe, Fstm.
Lepidodendron veltheimianum, Stbg.
,, *volkmannianum*, Stbg.

These beds appear, according to Clarke's paper on the sedimentary formations of New South Wales (p. 29), to pass down into the *Lepidodendron* sandstone, but the statement is not quite sufficiently clear. According to G. Mackenzie's section of Stroud, published by Feistmantel, marine beds occur again between the plant beds and the *Lepidodendron* sandstones, and contain *Conularia, Fenestella, Productus*, and *Crinoidea*, but this marine fauna has not yet been closely studied.

Feistmantel regards the flora of these beds as certainly indicative that they are of the carboniferous limestone age.

This fact is one more reason for assigning the marine beds of Stony Creek to the age of the upper coal-measures.

[1] Rec. Geol. Surv. Ind. Vol. XIX., p. 44.

The Newcastle beds.—These consist mainly of sandstones with subordinate shales and coal seams. Their sectional thickness is unknown to me, but Clarke in a section of Burragorang gives a thickness of 716 feet. The seams yield a fairly good coal and are worked in numerous pits.

Of organic remains plants seem very common, but marine animals are entirely wanting. Up to the present the following have been described :—

Phyllotheca australis, McCoy.
Vertebraria australis, McCoy.
Sphenopteris lobifolia, Morr.
„ *alata, Bgt.*
„ „ *var. exilis, Morr.*
„ *hastata, McCoy.*
„ *germana, McCoy.*
„ *plumosa, McCoy.*
„ *flexuosa, McCoy.*
Glossopteris browniana, Bgt.
„ *linearis, McCoy.*
„ *ampla, Dana.*
„ *reticula, Dana*
„ *cordata, Dana.*
„ *wilkinsoni, Fstm.*
„ *parallela, Fstm.*
Gangamopteris angustifolia, McCoy.
„ *clarkiana, Fstm.*
Caulopteris adamsi, Fstm.
Zeugophyllites elongatus, Morr.
Næggerathiopsis spathulata, Dana.
„ *media, Dana.*
Brachyphyllum australe, Fstm.

Of animal remains only one fish, *Urosthenes australis, Dana*, was found.

The beds are most closely connected with the underlying ones, and were only distinguished from the older division because of the absence of marine fossils and because of certain differences in the flora. They probably stand in a similar relation to the Muree beds, as in India the Kárharbári beds do to the Tálchir beds.

These beds are of special interest, as it was they which, together with the underlying Muree beds (whose separation was not at first attempted, but was only introduced by Feistmantel), led to a comparison of the Indian coal-measures with the Australian, and thus caused the former to be regarded as palæozoic. Although Feistmantel has lately attempted to show that the floras of the Damuda beds and of the Newcastle beds do not agree so closely as has been hitherto assumed, yet a large number of the species is identical. Feistmantel places the Damuda beds parallel only with the next higher sub-division, the Hawksbury beds.

The Hawksbury beds.—These are thick coarse-grained sandstones which show singular weathering forms, especially in the upper beds, and often form rock masses which are not unlike ruined castles. At the base, immediately above the Newcastle beds, come dark violet-red marls rarely interrupted by sandstones, while higher up sandstones predominate. They show yellowish or reddish to reddish-brown colours and pass frequently into conglomerates. Beds of brown ironstone in part impregnated with carbon are not rare, some attain great thickness and are then mined.

The total thickness is given by Clarke at 800 to 1,000 feet.

Fossils are not common in this sub-division, only a couple of fishes and a few plants having as yet been found. They represent the following species:—

Cleithrolepis granulatus, Eg.
Myriolepis clarkei, Eg
Thinnfeldia odontopteroides, Fstm.
Sphenopteris, sp.
Odontopteris, sp.

It is noteworthy that in these beds again traces of ice-action are recorded. The shale beds often show a very peculiar structure. Great angular blocks of shale are often met lying together in great confusion, the spaces between them being filled with sand or small gravel. Wilkinson,[1] who first drew attention to this believes that great moving masses of ice were the cause of these appearances, that in other words they are appearances caused by the stranding of ice floes.

That ice action participated in the formation of this deposit was also confirmed by Haast.[2]

As mentioned above, the Hawksbury beds were correlated by Feistmantel with the Indian Tálchirs, and perhaps partly with the Damudas. This correlation is however not based on palæontological data, but on the fact that traces of ice-action are found in both formations. This correlation has, however, been lately much called in question by R. D. Oldham,[3] and it must be conceded that such correlation is not a very natural one. But it appears equally unnatural to correlate the Newcastle beds with the Damudas, as is done by Oldham. Much the most probable correlation is to regard the Tálchirs as the equivalent of the Muree beds, and the Kárharbáris as equivalent of the Newcastle beds. *Gangamopteris* and *Glossopteris* occur frequently in both formations, and *Gangamopteris* is common to both. The Damudas would then appear to have to be considered as of Hawksbury age, but the possibility must not be lost sight of that the Damudas may yet in part reach down to the Newcastle beds.

Wianamatta beds.—According to Clarke, these beds appear to follow the Hawksbury's with imperfect conformity; and here appears for the first time a break in sequence of the Australian coal-measures. The Hawksburys appear to have been considerably denuded before the Wianamattas were deposited. These latter consist mainly of soft shales and fine-grained sandstones which give rise to hills of rounded outline. I can nowhere find any statement of their thickness.

In the shales as well as in nodules of spherosiderite, fish and plant-remains are found, and up to the present the following species have been identified —

Palæoniscus antipodeus, Eg.
Cleithrolepis granulatus, Eg.
Thinnfeldia odontopteroides, Fstm.
Odontopteris microphylla, McCoy.
Pecopteris tenuifolia, McCoy.
Macrotæniopteris wianamatta, Fstm.

This flora is regarded by Feistmantel as Triassic, and treated as equivalent to the Indian Damudas.

[1] Trans. Roy. Soc. New South Wales, 1879 and 1884, XIII, p 105.
[2] Feistmantel, Rec. Geol. Surv. Ind. XIII, pp. 251-2.
[3] Rec. Geol. Surv. Ind. XIX, pp. 42-45.

The occurrence of *Thinnfeldia odontopteroides*, however, appears to me to point rather to a relationship with the Panchets. Of the fishes, *Palæoniscus* is generally regarded as Permian, while *Cleithrolepis* reminds one more of Mesozoic forms.

On the whole, the series of formations in New South Wales terminates with the Wianamatta beds: it is only here and there that yet younger beds have been found. Such beds have been described by Wilkinson as occurring in the Clarence River, and Feistmantel refers to two species of plants derived from them:—

Tæniopteris daintreei, McCoy.
Alethopteris australis, McCoy.

Both these species are important for the correct classification of particular formations which have been found elsewhere in Australia.

So far this sketch has had reference only to the succession of deposits in New South Wales, but we must turn our eyes towards the other provinces of Eastern Australia.

In Queensland, coal-measures are known belonging to two periods. The older of these, which lies more to the north, contains marine fossils of Carboniferous type and remains of *Glossopteris*, *Schizopteris* and *Pecopteris*. In these formations also traces of ice-action have been pointed out.[1]

The more southerly coal-measures are younger in age, and their flora shows the following species:—

Sphenopteris elongata, Carr.
Thinnfeldia odontopteroides, (Morr.) Fstm.
Cyclopteris cuneata, Carr.
Tæniopteris daintreei, McCoy.
Sagenopteris rhoifolia, Presl.
Otozamites cf. mandelslohi. Knor.
Cardiocarpum australe, Carr.

Feistmantel correlates the beds containing this flora with the youngest beds in New South Wales as seen in the Clarence River.

In Victoria the series is rather more complete. At the base are sandstones, which are specially well exposed at Iguana Creek, and which should probably be regarded as Devonian. They have yielded the following plant species:—

Sphenopteris iguanensis, McCoy.
Ancimites iguanensis, McCoy.
Archæopteris howitti, McCoy.
Cordaites australis, McCoy.

Over these follow sandstones known as the Avon River sandstones, which have yielded *Lepidodendron australe*. Feistmantel considers these formations to be Carboniferous.

The next higher sub-division is of great importance. It bears the name of the Bacchus-Marsh sandstone, and includes great boulder deposits of unquestionably glacial origin. The plant-remains furnished by the sub-division are—

Gangamopteris obliqua, McCoy.
" *angustifolia, McCoy.*
" *spatulata, McCoy.*

Feistmantel has connected these beds with the Hawksbury beds of New South

[1] R. L. Jack, Report on the Bowen-River Coalfield, Brisbane, 1879.

Wales; but it appears much more natural to correlate them with the Muree and New castle beds, and all of them with the Tálchir-Kárharbáris of India.

The uppermost division recognised in Victoria is that of the Bellarine beds. They are very widespread and are of great thickness. Coal seams occur, but are of small thickness and extent. Plant-remains appear to be numerous, and up to the present the following species have been described :—

Phyllotheca australis, Bgt.
Alethopteris australis, Morr.
Tæniopteris daintreei, McCoy.
Podozamites barklyi, McCoy.
Zamites ellipticus, McCoy.
,, longifolius, McCoy.

This flora points with great probability to a Mesozoic age of the beds containing it, and Feistmantel correlates also the Bellarine beds with those on the Clarence River in New South Wales, and the upper coal-measures in Queensland. In India the Rájmahál and Jabalpur beds should probably be considered equivalents of the formations first named.

The above are rough outlines of the conditions met with in South Africa, India, and Australia, and it will be well to bring together in tabular form the results obtained up to the present, in order to obtain a general view before we proceed to make further deductions :—

	South Africa.	India.	Eastern Australia.
Neocomian	Uitenhage	Cutch { Plant beds. Marine beds, Tithonian.	? Marine beds in Queensland.
Tithonian.	?		
? Rhætic and Jurassic	Stormberg beds.	Jabalpur beds Kota Maleri beds Rájmahál beds	Bellarine beds. Clarence River beds. Southern coalfields, Queensland.
? Lowest Trias.	Beaufort beds	Panchet beds	Wianamatta beds. *Unconformity.*
Permian.	Koonap beds	Damuda beds	Hawksbury beds (glacial).
Upper Carboniferous	*Unconformity*	Kárharbári beds	Newcastle beds
	Ecca beds (glacial)	Tálchir beds (glacial)	Stony Creek beds. Bacchus Marsh beds (glacial)
Lower Carboniferous.	Lepidodendron beds	Resting unconformably on crystalline rocks.	Stroud and Port Stephen's beds, &c. Lepidodendron beds.
Devonian.	Marine Devonian	......	Marine Devonian.

From what has been said above it is evident that in South Africa, equally with India and Eastern Australia, great rock systems occur, which are rather nearly related to each other, and certainly agree with each other far more closely than with any series yet known in Europe or America. The greater part of these formations are evidently of fresh-water origin; and huge lakes and vast river systems must have occupied the regions where to-day we find the formations in question.

This observation led long since to the assumption of a great continent which in early geological periods extended over a great part of the southern hemisphere, and which in area may not have been greatly less than the present Asia-European continent.[1]

The story of this continent seems to have been a highly singular one. Instead of the great chains of foldings which compose the mountain elevations in the northern hemisphere, and form thus to some extent the skeleton of the continents; we here find table-shaped mountains built up of horizontal rock masses. These, it is true, rest on folded rocks, but the rocks effected by the folding action are principally archaic. Already in the Devonian period we see the intensity of the folding forces greatly decreased, great regions like South Africa and India show the Devonian formations mostly in horizontal positions, and whatever followed was only tilted out of its horizontal position here and there quite locally.

While the fold-making action was decreasing more and more on this part of the earth's surface, immense fallings-in appear simultaneously to have led more and more to the breaking up of the once existing vast continent. We know from the distribution of the marine deposits, that in the Jurassic period the old continents had already been separated into three independent parts; and that Africa, India, and Australia were already divided by arms of the sea: in the Triassic period on the contrary, Africa was probably still connected with India, but Australia had already then become independent.

Thus instead of increasing, the old continents shrank more and more; and probably somewhat at the same rate at which Europe and Asia emerged from the sea, the latter overflowed immense areas that were formerly *terra firma*.

At the present day only small fragments remain of the once existing southern continent, but these by the thickness of the horizontally-bedded fresh-water-formations and the mightiness of the physical processes which they reveal, allow us to draw conclusions as to the vast extent of the land to which they once belonged.

The rock systems above treated of were none of them deposited till after the cessation of the folding action. We find all the beds nearly horizontal, forming either plateau regions, or occupying shallow basins, and important stratigraphical disturbances are either local or only to be enumerated as exceptional cases of rare occurrence. The period of the fallings-in had commenced before the formation of the above-described rock systems had been finally completed. Vast areas, which had formerly been *terra firma*, were more and more submerged; and the witnesses of these events are the scanty marine deposits of jurassic and cretaceous age which we still meet with along the margins of the few remaining fragments of the ancient continent in Africa, India, and Australia.

[1] H. F. Blanford, Quart. Jour. Geol. Soc. Lond. XXXI, 1875, p. 519. Waagen Denkschr. Kais. Akad. d. W. Wien, 1878. Waagen, Rec. Geol. Surv. Ind. 1878.

It was on this continent that in times long gone by events transpired which remind one strongly of the events which happened during the quarternary glacial period in the northern hemisphere; and there was probably a time when this southern continent was mainly covered with vast masses of ice.

But when was that time? This is the great question that we have now to approach.

It has already been pointed out repeatedly that the palæontological finds in the above-described rock systems give remarkably contradictory results. If we turn merely to the Uitenhage and Cutch beds, we find in them a marine fauna pointing to a Neocomian and Tithonian age for those formations; while the plant-remains met with in the same beds are universally judged as pointing to a lower Oolitic age, and specially to the horizon of the Scarborough beds.

These contradictions between the animal and vegetable remains recur more or less in all the different sub-divisions of the systems, and become very markedly conspicuous in the Autralian Muree beds, where again marine deposits occur alternating with plant beds.

The fossil plants occurring in these beds were, and are still to-day, pronounced by McCoy, to be positively mesozoic; because in Europe the genus *Glossopteris* has only been found in the Russian Jura and in Tertiary formations, and could therefore hardly be of greater than mesozoic age in Australia. When at a later date, Feistmantel condescended to admit the Australian formations into the palæozoic epoch, it was done far less because the flora required it, than because of the marine animal remains occurring in these beds, which have a distinctly palæozoic character. But as the succession of beds, whether above or below the disputed formations, yielded no perfectly certain data for determining the age; the followers of the mesozoic age theory were at liberty to say "the plant-remains point distinctly to a mesozoic age of the entire system, and thus it is probable that in Australia the palæozoic animal forms survived longer than in Europe, and reached up into mesozoic times." In support of this the fact could be adduced that in the present fauna and flora of Australia old types reaching up from earlier times are for the most part common, and that therefore in earlier times other old types might there be found reaching up higher than elsewhere. On the other hand, however, the species in M. de Koninck's work were so widely framed that the designation of species there used could really only be valid as group names. I myself was for some time not quite disinclined to join in these views of the phytopalæontologists, for which reason I have here and there spoken of the "So called-carboniferous deposits of Australia."

The question as to the age of these beds is now, however, of quite special interest, because of the glacial formations which are met with at equivalent horizons.

As I have already memtioned above, W. T. Blanford has striven with much skill to make a Permian age probable for the Tálchir-Kárharbári-Damuda series, and for the equivalent beds in Africa and Australia; but it was impossible for him to adduce anything more than proofs of probability, and thus no further conclusion could be based on his deductions.

It was reserved for recent times to clear up the subject; and it was the discoveries, more especially of the Würtembergian, Dr. H. Warth, in the Salt-Range which let the whole question appear in a new light.

IV.—THE SALT-RANGE.

It has long been known that in the Salt-Range also, formations are not seldom met with which have doubtless been formed under the co-operation of ice.

I have myself seen and studied these formations in many places, but till now had no opportunity of expressing my opinions about them publicly. Even now I feel somewhat embarrassed about speaking on this subject, for a remarkably unlucky star rules over everything that I publish on the general relations of the Salt-Range. Every time I am rebuffed in a manner that is really not seemly. Expressions such as "ignorance," "charlatanism," or "it would be best to regard such a paper as unpublished," are among the terms of endearment I am thought worthy of. If the writers of these knew how that I take counsel with myself for years, and consider from all points any important view before I publish it, they would perhaps judge me more indulgently. Hitherto it has not been possible for them to disprove my position; consequently I feel myself justified in still holding fast to the views which have given occasion for such harsh criticism.

The succession of beds in the Salt-Range, includes as is well known, the rock systems from the Eocene to about the Devonian (not to refer to the younger tertiary sandstones of the Potwar plateau) without showing any specially important gaps. It is equally well known that in different parts of the Salt-Range the succession of beds is very variously represented. I must here also use the nomenclature introduced by Wynne, as the application of European terms would involve too concrete a correlation, and does not at the present moment seem quite desirable.

In the eastern part of the Salt-Range the succession is as follows:—

Nummulitic beds.
Olive group.[1]
Beds with salt crystal pseudomorphs.
Magnesian sandstone.
Neobolus beds.
Purple sandstone.
Salt-marl and rock-salt.

Except the neobolus beds, the olive group, and the nummulitic limestone; this whole series of beds has yielded hardly any organic remains worth naming, and it would have been hardly possible to have determined the age of any one group in this succession from such evidence as existed till quite lately.

In the western part of the Salt-Range on the contrary, matters were quite different, as some beds occur here rich in well-preserved and characteristic fossils. The succession of beds here is the following:—

Nummulitic beds.
Olive group.
Variegated sandstone (Jurassic).
Ceratite beds.
Productus limestone (Permian).
Speckled sandstone.

[1] This term is now discarded; the greater part, if not the whole, in certain localities, of the series being now known as the "speckled sandstones."—*Ed.*

Magnesian sandstone } hardly separable here ; they thin out westward.
Neobulus bed }
Purple sandstone, thinning out westward.
Salt-marl and rock-salt.

The sub-division is seen to be much more varied here, and the age of several of the formations can be accurately determined. For our present purpose the "speckled sandstone" is the most important, and we will consider it more closely. By the "speckled sandstone" I understand not only what Wynne called by this name in the Salt-Range proper, but also the equivalents on this horizon in the west (the boulder group) and in the east as well (the olive group in part).

For clearer comprehension of the succession, however, it must be pointed out that the nummulitic beds and the olive group (more correctly the *Cardita beaumonti* beds) rest unconformably on all the underlying groups, and thus, if followed from west to east, they lie successively on Jurassics, ceratite beds, Permians and speckled sandstones—a circumstance which in part also causes the difference in the succession of beds in the eastern and western parts of the range. Besides this I must here rely entirely on Wynne's report, as all my own observations are woven into it. The report is in fact to be regarded as a joint one, as far as the observations in the field have to be considered. It should have been a joint one in its execution, but this was prevented by my repeated serious illnesses ; and thus Wynne was compelled to undertake the working out of it by himself. The employment of the material has in consequence certainly often led to the different results, as if I would have disposed of them could I have influenced their being worked out. I cannot, however, for that reason entirely give up my own views, and Mr. Wynne must allow me to give them expression here and there. It is very far from my intention to ignore, on that account, the great credit Mr. Wynne has deserved by the working out of the map ; or to fail to acknowledge the admirable accuracy of his map. But now, if after having worked out the fossil faunas of the Salt-Range in great measure, I find myself constrained to lay yet greater stress on various points in the apprehension of which I did not agree with Mr. Wynne ; it will be owing to the progress made through the more exact understanding, palæontologically, of the beds. Mr. Wynne cannot possibly wish to assert that it is impossible to attain to a better knowledge of the beds than that given in his report, and doubtless his own views will have become clearer within the last ten years, as is the case with every savant unless he absolutely closes his ear against all progress.

As I stated in my introduction to the Salt-Range Fossils, the palæozoic formations of the Salt-Range are divisible into two great groups, of which the one consists of the purple sandstone and the salt-marl, the other of the higher-lying beds.[1]

[1] R. D. Oldham believes (according to a friendly communication from him) that he can show an unconformability below the speckled sandstone, while the underlying beds down to the saline series form a consistent and conformable series. As far as the unconformability is concerned, I have no objection to make to it, on the contrary, I believe I myself made observations which allow it to appear probable, at least at certain points ; but I nevertheless believe that all the beds underlying this break cannot be regarded as belonging to one group. The magnesian sandstone and neobolus beds belong together, as certainly as it is sure that their fauna is related to that of the overlying beds although they are unconformable. But the purple sandstone shows such very close relation to the saline series, that the two can hardly be separated. The base of the latter is not exposed in the Salt-Range proper. Proceeding westward, the saline

The upper group, on the contrary, includes many littoral formations and may have been deposited by a sea that advanced from the north-west. The immense sandstone accumulations to the east of the Salt-Range, which thin out to inconsiderable beds and almost die out, appear to me to be explicable as "dune" formations, and I further believe that they indicate the embouchure of a great river which flowing from the south-east, in those long-past times reached the sea in this region. There are many points on which to base such an assumption. *Imprimis*, the Neobolus beds, as the horny-shelled Brachiopods, had probably lived in the same kind of places as the existing *lingulæ* which frequently colonize the muddy or sandy bottoms in the vicinity of river mouths; and secondly, the beds with pseudomorphic salt-crystals, which indicate a tract overflowed alternately by fresh and salt water, conditions which appear most frequently in lagoons surrounding estuaries.

Under these sandstone formations, the speckled sandstones are, as pointed out above, those which extend furthest to the west, and which for many other reasons are the most important and interesting. In their uppermost beds they include a marine fauna which is very nearly related to the fauna of the Productus limestone, and for which reason I designated this formation the Lower Productus limestone. The percentage of true carboniferous species in these beds is greater than in the Productus limestone proper, and I have therefore thought it necessary to join these beds to the coal-measures specially as *Fusulina longissima, Moll.*, occurs here numerously. Perhaps they should only be correlated with the very uppermost beds of this group, *e.g.*, the Nebraska beds or the Artinsk sandstones, because of the frequent occurrence of the genera *Strophalosia* and *Aulosteges*.

Somewhat lower down in these sandstones occur boulder beds, which are to the northward and westward, the only representatives of the whole group, and occur there very constantly below the fossiliferous beds and the Permian limestones.

Unfortunately I cannot, with reference to these boulder formations, enter into as full detail as might appear desirable, partly because of the excessive length this paper would then acquire, partly for the reason that in the last volume of the Salt-Range Fossils a detailed sketch of the Salt-Range will be given, which must not be anticipated here.[1]

series continues to include more and more grey dolomites and gypsums with quartz crystals, and west of the Indus seems to pass into Wynne's generally grey-coloured upper gypsum and dolomite group. The base of this group, however, consists again of red sandstones identical with the purple sandstones of the Salt-Range proper. Thus the saline series appears altogether to be only an inclusion in a vast formation of red sandstone, which must clearly be regarded as a distinct formation. I regard this formation as an equivalent of the Vindhyans of the Indian peninsula; and from its position below the Carboniferous neobolus beds, as of Devonian age. The two groups have a very different distribution, the older occurs only in the south, and disappears in part where the other trends to the north; it would appear that the beds composing this group were formed in a great basin which extended south-eastward, probably an inland basin, and that the open sea of that part would have to be sought for further to the north.

[1] A considerable amount of new information concerning this boulder bed has in the meantime been gained through the work of Dr. Warth and R. D. Oldham (See Rec. G. S. of I., XIX, pp. 1, 22, 127, 131; XX, p. 117; XXI, p. 34), while I myself can further supplement this by my own observations this year of the decided unconformity of this boulder-bed to the underlying Salt-Pseudomorph zone, in the Khewra portion of the Salt-Range, where also, the Talchir facies of the boulder bed is remarkable.—W. K.

To the west (Trans-Indus), especially near Kingriali, Wynne distinguishes a very peculiar boulder group consisting of grey clays with subordinate sandstones and gypsums, and containing in its upper part a boulder bed of considerable thickness. The boulders are well smoothed and often marked by scratches. This boulder group is followed here as elsewhere above the speckled sandstones by the Permian limestones.

To the north-east of this lies Kalabagh, which indicates the most northerly point to which the range has deviated from its general course. Here also on the left bank of the Indus begins the Salt-Range proper, with a group of hills called the Tredian hills. Here the conglomerates are specially well developed, and are described by Wynne as follows: [1]

"The carboniferous limestones below often contain much chert, both black and white; while grey conglomerates and sandstone bands occur in the dark conglomeratic purple clay above the salt-marl. * * * * Immediately over the earthy part is a large boulder-conglomerate containing blocks of granite, syenite, and other crystalline rocks 2 feet in diameter; this conglomerate, if it has not slipped upon itself, may be 155 feet in thickness." Above this occur traces of the speckled sandstone.

We herewith enter upon the domain of the true speckled sandstone. This section is, as Wynne himself describes it, conglomeratic in many places, and the conglomerates appear frequently as true boulder accumulations, particularly in the region of Makrach and Sardi. As is usually the case, these boulder beds are not too regularly stratified, and it is hard to say whether they occur at absolutely the same horizon at different places; they are, however, irrespective of small vertical differences, geologically speaking of the same age. The position is always such that one must conceive the boulder beds as underlying the *Fusulina* beds.

The speckled sandstone attains its greatest development between Varcha and Narsingpohar, and from there thins out rapidly to the eastward, but without losing its boulder accumulations. Quite gradually, the intercalated clays assume a red colour, but the boulder beds become green; and thus two new groups are developed, namely, the "pseudomorphic salt-crystal zone and the conglomerates of the olive group." The most western point from which Wynne quotes the boulder conglomerates of the "Olive group" is Karuli. Here they lie upon the speckled sandstone, and probably on the middle division of that group. Still further to the west the olive group is, it is true, also clearly developed, but here, as for example at Nilawan, it rests on the fossiliferous beds of the Lower Productus limestone. No trace exists of any boulder formations at the base of the group, and we must descend to the speckled sandstone to find any such again.

The boulder conglomerates of the olive group have of late attracted special attention, as fossils have been found in them which agree with fossils obtained from the Australian marine Carboniferous beds. I published a note [2] on these, but by so doing again stirred up a hornet's nest, and was rebuffed by R. D. Oldham in anything but a civil style.[3]

The olive series, as described by Wynne, contains in its upper division an equi-

[1] Mem. Geol. Surv. Ind., Vol. XIV, p. 258.
[2] Rec. Geol. Surv. Ind., XIX 1886, p. 2.
[3] Rec. Geol. Surv. Ind., XIX, part II.

valent of the *Cardita beaumonti* beds of Sind; in the lower division the much contested boulder beds. In these latter, nodules[1] of clayey sandstones were discovered by Warth, which contain inumerable specimens of *Conularia.*

These nodules form a thin bed in the uppermost part of the boulder bed, and have up to the present yielded the following fauna:—

Bucania cf. kattaensis, Waagen.
Conularia lævigata, Morr.
" *tenuistriata, McCoy.*
" *cf. irregularis, Kon.*
Nucula sp. ind.
Atomodesma (?) warthi, Waagen.
Aviculopecten cf. limæformis, Morr.
Discina, sp.
Serpulites warthi, Waagen.
" *tuba, Waagen.*

To these I can now add *Spirifer vespertilio, Sow.*, from specimens recently sent over by Dr. Warth. This entire fauna is distinctly palæozoic, and there is not a single species present pointing to other formations. Four of the species are identical with Australian carboniferous species, namely:—

Conularia lævigata, Morr.
" *tenuistriata, McCoy.*
Aviculopecten cf. limæformis, Morr.
Spirifer vespertilio, Sow.

A *Bucania cf. kattaensis, Waagen,* is comparable with another out of the uppermost divison of the speckled sandstone, the so-called lower productus limestone.

According to Wynne and Oldham, these nodules occur as washed-up specimens. And as chief proof of this the rare occurrence of rolled specimens of *conularia* is adduced, and also the fact that the nodules do not contain the organic remains in their centre like proper concretions, but that the fossils appear cut off by the surface of the nodules in the most various ways; for which reason they must be regarded as rolled rock fragments.

As regards this last proof, it is of no value. I need only refer to the quartzite nodules in our Silurian stage Dd 1, which show precisely the same conditions, but of which it is known that they contain precisely the same fossils as the shales in which they lie, and where, therefore, there is no room for any doubt that both are contemporaneous, and that the nodules cannot possibly have been transported. Here in Bohemia also, minute nodules which bear on their outside fragments of rolled-up *trilobites* or similar organic remains, are found here and there with the other quartzite nodules. They would certainly be regarded as rolled pebbles if they did occur together with other fossils, and contain the same species. This is manifestly an example of imperfect formation of nodules.

The apparently rolled specimens of *conularia* may probably be explained in this way; but on this point I cannot express a positive opinion, as I have not seen the specimens examined by Wynne.

H. Warth sent me lately such an apparently rolled specimen of a *conularia,* which

[1] And pebbles, as described by Warth and Oldham.—W. K.

at the first glance looks certainly very much as if it had been rolled. On closer examination, however, various doubts arise.

In the first place, the size of the specimen, which measures 60 millimetres in length, and 20 millimetres in width at the upper end, but is only 11 millimetres thick. When such a thin elongated body of soft sandstone is exposed to such rough treatment as it must necessarily have undergone when moved along with the conglomerate masses, it is certainly very astonishing that it was not broken into smaller fragments. Then, two of its sides and one edge had been preserved almost intact, although covered with the most delicate sculpturing. Now, an angle is certainly one of the most prominent parts of the shell, and must, when rolling takes place, be first worn off. Of the well-preserved sides, the broader one certainly is concave, and might in consequence have escaped the effects of being rolled, but the other is, in consequence of a peculiar deformity of the specimen, much bellied out. Yet here also the most delicate sculpturing is preserved. I must here remark that the specimen sent to me by Warth is quite enclosed by the matrix, a coarse conglomerate sandstone, and that thus the objection that the piece was perhaps derived from a larger rolled fragment whereby the well-preserved sides being enclosed in the fragment were protected from the wear and tear of rolling, falls to the ground entirely.

Thus in this case also it appears more probable on closer study, that the peculiar preservation of the specimen was due rather to incomplete nodule-formation than to rolling. If the specimen had really been transported and embedded for a second time, it cannot have been brought more than a couple of thousand paces, otherwise the preservation of the sculpturing in particular parts would be utterly inexplicable.

Distinct proof of the "washed up" character of the nodules appears to me not to have been brought forward in Wynne's and Oldham's statements. That would only have been accomplished if they had found fossils of more recent age mixed with older ones. Violently though Oldham defends his views, he cannot produce such evidence.

For all that, I certainly do not assert that the possiblity of the washed up nature of the nodules is absolutely excluded, as I have not been able to revisit the localities since the discovery of the nodules; but a probability of that origin does not appear.

Even if they were washed up, they can only have been derived from a bed differing but little in age from their present site: nor can their original home be far removed from the place where they are now found. A proof of this is the completeness (? restrictedness[1]) of the fauna which they include, and which points to a common site and common origin. But such completeness can only be preserved when the bed which encloses the specimens has been but lately formed (and thus more recent formations could not have been affected by denudation), and when the specimens were only transported a short distance.

If we look around among the formations of the Salt-Range to see from which the nodules might possibly have been derived, if derived they were; we see that it is the magnesian sandstone alone with the Neobolus beds which could have yielded such

[1] Translator, R. B. F.

specimens. But if this be the case, and the nodules emanate from the magnesian sandstone, then this formation must advance upward suddenly into age of the Coal-measures, though they have hitherto been regarded by me as lower Carboniferous.

Shall this be the revision that my views on the Salt-Range are to undergo, as was hinted by Medlicott? Fresh facts were lately collected by Dr. Warth, which threw much new light on the whole question.

In the Nilawan, Warth found the *Conularia* nodules in boulder beds, which appear to follow immediately above the Neobolus beds, and which certainly lie at the base of the speckled sandstone. Here there is now no doubt possible that the *conularia* nodules are older than the ***Fusulina*** beds which occur in the immediate vicinity of the place of discovery.

There is yet something to be said about the age of the boulder bed. It was regarded by Wynne as Cretaceous, as he united it with the overlying *Cardita beaumonti* beds, which may probably be regarded as uppermost cretaceous, or as an equivalent of the Lamarie group or of the Liburnian stage.

R. D. Oldham insisted most strongly on the cretaceous age of the boulder bed, and maintains that it is unconformable to the underlying beds. Of such an unconformability neither Mr. Wynne nor I myself have seen anything. On the contrary, I have measured sections in which a perfect transition from the underlying beds of the salt crystal zone to the boulder beds could be traced, which was effected by an alternation of green and red sandstones and shales.

But in this respect also there is no reason for being compelled to unite the boulder beds with the upper instead of the lower beds. That such a boulder bed should not always lie as regularly on its soft foundation as is the rule with other formations is in the nature of things. But then such a deposit came to pass under quite unusual circumstances.

In these boulder beds of the olive series [1] their glacial origin is as distinctly expressed as it can possibly be wished.

The boulders and shingle consist most largely of red porphyry, and innumerable specimens show distinct grindings and scratchings. Very many are ground on different sides—a proof that they were at various times impacted in the ice-mass in different positions, while it was still moving. I give herewith illustrations (Plate 1.) of two such pebbles, the larger consisting of porphyry, the smaller of a blackish-grey aphanitic rock, and of which the larger is polished on the back and front sides, the smaller on three contiguous sides. The direction of the scratches is different on each polished surface, but scratches often occur on the same surface running in directions crossing each other.

If we review all that has been said up to the present with regard to the boulder beds of the olive series, we shall arrive at the following conclusion :—

(1) The boulder beds appear in the olive series just where it is in contact with [2] the speckled sandstone; while further to the west they are only found in the speckled sandstone in which they occur frequently.

[1] "Olive series" might here be better read "Eastern Salt-Range."—W. K.

[2] ? For "is in contact with," one might here read "passes longitudinally into" or "replaced by."—W. K.

(2) The speckled sandstone can, from its position below the Permian limestones and from the fossil contents of its uppermost beds, be regarded as certainly an equivalent of the uppermost section of the coal-measures.

(3) In the boulder beds of the olive series are nodules, in which, out of 11 species of fossils contained in them, 5 can be identified with species from the Australian coal-measures, and one identifiable with a species from the speckled sandstones.

(4) These *conularia* nodules which occur in the boulder beds of the olive series were lately also discovered in boulder beds in the Nilawan, which certainly lie below the *Fusulina* beds.

As all these conclusions point with great certainty in the same direction, it is difficult not to assume that the boulder beds of the olive series are to be regarded as a partial equivalent of the speckled sandstone, and are approximately of the same geological age as the boulder beds which are met with so largely developed at the base of the Permian limestone.

Hereby we have gained for the Salt-Range a great uniform glacial horizon, which is of very special importance for a right understanding of the great questions which have to be solved here.

It is true that quite lately voices have been heard giving expression to the opposite view; and R. D. Oldham asserts, in a paper in the *Geological Magazine*, that not less than four distinct horizons exist. Unfortunately no new facts have been adduced, and so Oldham's view cannot indeed bring us to give up our own well-weighed view. Such acceptations of the case always go back to Croll's theory that the glacial periods on the earth were as common and as cheap as blackberries—a theory which is in no way supported by the geological facts observed in general. The view that all the glacial formations in the Salt-Range should be reckoned to one and the same group, in no way strains the observations made by Wynne or myself, and can therefore pass as the right one till striking proofs to the contrary are brought forward I shall have an opportunity further on of returning to the statements about the existence of numerous glacial horizons one above the other in one and the same region.

Other statements made by Oldham in the same paper deserve fuller mention, as they add fresh tracts of glacial formation to those already known in India, and at the same time give information as to whence the glacial gravels of the Salt-Range were probably derived.

In the great Indian desert which stretches from the Arvali range to the Indus, Oldham found, near to the town of Pokran, a land surface consisting of porphyry and syenite which is completely covered with scratches and striations. On this surface lies an extremely tenacious glacial mass, which Oldham claims as Till or Moraine profonde, while in the neighbourhood bedded glacial formations, manifestly of marine origin, occur widely distributed. In the Moraine profonde are only gravels of porphyry and syenite; in the marine formations on the contrary chiefly gneisses and granites which emanate from the Arvali range. Oldham believes, then, that the glacial gravels of the Salt-Range also came from the south, partly from the porphyritic continent, partly from the Arvali Mountains. Oldham assumes also for these formations the age of the Tálchirs.

In a former paper I observed already that I regarded the glacial formations of

the Salt-Range as marine throughout; but I believe not only that great glaciers descended from the Arvalis to the sea, as is assumed by Oldham, and there broke up into icebergs, but much more that the great river, the probable existence of whose mouth in the eastern Salt-Range I mentioned above, carried down to the sea vast floating masses of ice.

However all this may have been arranged, it retires completely into the background in comparison with the great general questions which have yet to be solved here.

The most important of these is the question as to the age of the glacial beds. We have established for the glacial deposits in Australia and Africa that they rest on lower carboniferous formations, and in Australia they contain a marine fauna which points to the age of upper coal-measures. This is opposed by the accompanying plant-remains which are regarded as mesozoic.

We have now, however, become acquainted with glacial deposits which underlie Permian limestones, and actually contain indications of the Australian coal-measure fauna which there lies in glacial beds. According, therefore, to all the laws of synchronism there can be no great doubt that the glacial formations of the Salt-Range are to be regarded as approximately contemporaneous with those of Australia, in which the same fauna occurs. Thus, then, the geological age of the glacial period under consideration would seem to be altogether settled.

In Australia we have unquestionably lower Carboniferous deposits, Culm measures as their foundation: in the Salt-Range we have beds of undoubted Permian age overlying them directly. Thus nothing remains for us but to assume that the glacial events which we have been discussing took place at a time when elsewhere the upper coal-measures were being formed. The conclusion of the phytopalæontologists, which was referred to above, that in Australia the plants must be the determinants, and that the palæozoic animal types must there have lived on into the mesozoic times indicated by the plant-remains, has thus become quite untenable, and we know now for certain that in Australia, Africa and India, a flora of mesozoic type appears already at the time of the coal-measures. But this is a result of the very widest range, that includes within itself a multitude of further conclusions.

First of all let it be pointed out that the new flora appears elsewere with glacial formations, which is a clear proof that it could bear low temperature and was at the least capable of resisting night frosts. In Australia, as in Africa, this new company of plants dispossesses a series of true carboniferous plant types, as the *Calamites* and *Lepidodendra;* and the gap between the older and newer flora is so great that hardly a single genus is common to both. Under these circumstances, it is quite allowable to assume that the first distinctly palæozoic flora met its end through the advancing cold which the commencement of the glacial period diffused over the great southern continent. What else should have brought about this destruction, since at the same time on other parts of the earth's surface, where equally clear traces of the advent of severe cold are not to be traced, this same flora was at its highest development, and the formation of the coal-measures went on undisturbedly? We have therefore gained a measure for the temperature conditions to which the plant families unite their existence. The palæozic floras, consisting mostly of delicate organisms, were evidently unable to endure lower temperatures, and were bound

to perish as soon as more frequent and more severe frosts commenced. The younger flora on the contrary consisting of mesozoic types evidently contained organisms, which being stronger could resist the lower temperature, and were thus capable of accommodating themselves to more varied conditions of life.

A further inference arises necessarily out of the above, namely, that the younger flora, consisting of mesozoic plant types, was developed autochthonously in the great Africo-Indo-Australian continent; for we find in no country on earth the smallest tittle of evidence that will allow us to conclude that mesozoic plant types had developed anywhere in periods preceding the formation of the coal-measures, and had spread themselves by migration over the southern continent.

A *per contra* assumption immediately suggests itself: that the mesozoic floras of Europe which all show a great typical resemblance, are to be regarded as descendants of the palæozoic flora, which came to be developed on the southern continent during the coal-measure period.

The chief point, however, is always the proof of a glacial period which appeared on the southern continent during the coal-measure epoch, for all the other conclusions are based on this one fundamental fact. But this fact can no longer be doubted since so many observers in many quarters have, quite independently of each other, arrived at the unanimous result that the formations in question came to pass under the influence of ice. Only the settling the age of the formations was doubtful, but this can now be carried out with great certainty.

The glacial formations of this period are spread over an immense area of the earth's surface. They begin in about 40° south latitude and stretch away to about 35° north latitude, and in longitude from about 35° east of Ferro to 170° east, an area including more than a quarter of the earth's surface, and in extent and size not much inferior to that affected by the most intense action of the quaternary glacial epoch. But while during the quarternary glacial period the northern hemisphere suffered chiefly, and comparatively small extensions pushed down alongside the Andes and through New Zealand into the southern hemisphere, the chief episodes of the Carboniferous glacial period took place in the southern hemisphere, with the glacial deposits on the Afghan-Persia frontier which up to 35° north latitude are but of small extent.[1] All this is obviously correct only in its most general features. Very much is yet required to give us a clear picture of all the conditions, and many further studies will be necessary to complete the sketch here attempted. We ourselves must let our eyes travel still further, and first of all submit the Europe of that time to closer consideration.

V.—EUROPE.

Glacial formations have repeatedly been thought to have been discovered in deposits which precede the quarternary period more or less. We will here disregard Croll's statements, for he thought he could point out numerous glacial formations in every system, for these statements can hardly be accepted as made in earnest. Far more prudently does James Geikie express himself in his classical work, "The Great Ice Age;" for to him the glacial origin of certain beds appears

[1] According to Griesbach's data. Rec. Geol. Surv. Ind., Vol. XIX, p 57.

to be made out in two cases only. The conglomerates at the base of the Carboniferous in the south of Scotland, and the Permian boulder beds described by Ramsay, appear to him to be certainly glacial.

Unfortunately I could learn nothing in detail from the existing literature about the glacial horizon in the lower Carboniferous of Scotland (as to which it is really doubtful whether it should not be classed as Upper Devonian). I succeeded, indeed with great trouble, in procuring the descriptive text to the geological map, but could find no fuller information in it. Indeed, in England itself the view that these formations are glacial seems to have been given up again more or less. Archibald Geikie in his *Text-book of Geology* lays no great stress on these statements: and lately at a meeting of the Geological Society of London, striated pebbles derived from these beds were shown in order to prove how such scratched gravels could be produced in a secondary way by the sliding of the beds.

It is quite different with regard to the glacial horizon in the Permians which is by all authorities unanimously regarded as unquestionably glacial. I shall later on have an opportunity of inquiring more closely as to this Permian glacial horizon, but for the present we will confine ourselves to the Carboniferous proper. The glacial horizon above referred to at the base of the Scotch Carboniferous appears to be at the very least doubtful.

Only a year after Ramsay had shown the glacial nature of the Permian breccias in England, Godwin Austen[1] mentioned masses of rock out of the conglomerates underlying the coal-measures in France, which masses were of far too great dimensions to have been carried to the sites they now occupy by any other agency than that of floating ice. Although the blocks are described as more or less angular, such a fact, in the absence of other parallel facts, such as polished and striated gravels, hardly suffices to stamp such formations as certainly glacial. The formations may appear to some extent suspicious, but it is hardly possible to base further conclusions on such data, especially when they have been observed only singly and not at many places.

The same holds good probably with regard to the rounded rock masses known from Silesian coal-fields and the Ostraver basin, about which so much has been said of late.[2] These rounded masses occur in the coal itself, and are often of considerable weight (one block of granulite weighed 55 kilogrammes). These blocks had evidently fallen into the coal from above while it was still in a soft peaty condition, and it would appear that the distance whence they were borne must have been a considerable one. It is therefore all the more difficult to say how the transport may have been effected. It would be most easy to assume that ice had been the agent; but it is dangerous to draw such sweeping conclusions from such isolated facts, as other possibilities cannot be absolutely excluded. Various writers have already pointed out that trees can remove rock masses, entangled in their roots, over great distances, and that perhaps some such cause might be assumed to have operated in the cases in the coal-measures. It must certainly be borne in mind that the trees of those days were only occasionally possessed of a plexus of roots in which rock-masses could fix themselves; but on the other hand, the carrying power of those spongy

[1] Quart. Jour. Geol. Soc., Vol. XII, p. 58.

[2] See Stur., Jahrbuch d, K. K Reichsanstalt, 1835, Vol. XXXV, p. 627.

woods may have been greater than that of the compact woods of the existing trees. In any case, the conditions under which those rock-masses were transported must have been very unusual ones, as indicated by the very rare occurrence of such rounded masses in the coal-measures. Anyhow, the occurrence of those rounded masses does not suffice to demand the assumption of a quasi-glacial period at the time of the formations of those coal-measures in Europe.

If the occurrence of solitary large rock-masses in a bed, or even the presence of great accumulations of boulders, were a sufficient proof of once existing ice-action, then no region could well be richer in old glacial formations than the Gailthal Alps. Gigantic boulder beds occur there at very different horizons (green Carboniferous breccias, Uggowitz breccia, Verrucano conglomerate), and if only the general fashion of the rock is regarded, these formations might decidedly be considered glacial. In no case was I able to demonstrate specially the glacial character of these deposits. In the autumn of last year (1886), I specially visited the carboniferous outcrops of this character in the Nœtschgraben, near Bleiberg, on the occasion of several excursions.

The section of the Nœtschgraben was described by Suess[1] in his accustomed masterly style. The lowest exposed rocks are the Carboniferous limestones and shales which are described by Suess as follows:—"The beds underlying the argillo-micaceous shales have a similar composition, but are coarser. They contain quartz veins of precisely similar character to those in the argillo-micaceous shales. Somewhat deeper down appears a green tufa-like rock in company with another dark-green rock, the so-called diorite of Bleiberg. These two latter appear to be connected by transitions.

"Immediately below these lies in thick beds the light-coloured quartz conglomerate of the coal-measures, just as it appears at Kerschdorf at the base of the argillo-micaceous shales. It is accompanied by beds of sandstone, and sometimes these are underlaid by soft black shales whose surfaces are covered by minute spangles of mica. The thicker lower division of these contains various marine fossils, amongst which small *Producti* and *Fenestella plebeia* are the most common; traces of fern-fronds and *Calamites* are mixed up with them. Below these follow some beds of black carboniferous limestone full of *Productus giganteus* and *Poteriocrinus* and stems of *Cyathophyllum*. These are accompanied by a very hard dark-green breccia. Once more follows black shale and again black limestone with *Productus giganteus* and *Poteriocrinus*. These are underlaid in uninterrupted southerly dip by a yet greater mass of those green diorite rocks which were mentioned at the boundary against the argillo-micaceous shale, and with these reappears the dark breccia which acquires a very remarkable appearance, especially where its blackish-green matrix encloses numerous pieces of white granular limestone. Below the American smelting furnace a new bed of black limestone cropping out from below the above contains innumerable huge shells of *Productus* with *crinoidal* stems and *Cyathophyllum*, and is traversed by red threads of gypsum."

It is the dark-green breccias which appear as true boulder beds, and to which my observations have special reference.

[1] Suess, on the equivalents of the "Rothliegende" in the Southern Alps. Sitzungsbericht Akad. d. W. Vienna, 1868, Vol. LVII, pt. I.

These boulder beds are apparently, but somewhat irregularly, intercalated between the beds with *Productus giganteus*, and which have yielded the fauna described by M. de Koninck. The fossiliferous beds become equally irregular in the neighbourhood of the boulder accumulations, are much bent and seem often to have slid together. The boulder heaps themselves frequently show no bedding of any kind, consist mainly of boulders lying together in wild confusion, and often attaining nearly to the size of a cottage, but are otherwise very varied in size, and show as matrix a fine green sandy material (perhaps Diorite tufa?) that appears mixed with more or less coarse sand and gravel. The boulders themselves consist mostly of green, more or less, aphanitic rocks; but other rocks are not rare. They are never perfectly angular, but mostly half-rounded, and perfectly rolled pieces are also not wanting. The individual accumulations of boulders appear not to extend far horizontally. Despite very close searching I could not find a trace of a polished and scratched pebble, and it thus becomes very problematic whether one is dealing at all with a glacial formation. To me the idea that these boulder heaps came to pass by the co-operation of two other factors, appears much more probable; namely, surf and torrent actions. The torrents even to-day remove the same boulders from the beds and carry them away. The beds in the Nötschgraben were doubtless formed in a shallow very near the coast, and thus both factors could exert influence on the formation of the accumulations. The colossal power surf can display I was able to study during a whole winter on the coast of the Bay of Biscay, where rock-masses from 2 to 3 feet in diameter in each direction were dashed by the surf waves against the coast with such fury that the groaning of the rock-masses actually overpowered the thundering of the surf.

From this example it becomes clear how careful we should be not to pronounce any boulder bed to be glacial, unless on the one hand polished and scratched pebbles allow of a sure recognition of the glacial origin, and on the other hand, parallel facts permit of the idea of a radical change of climate.

Formations appearing on the most varied horizons in one and the same neighbourhood, which are all declared to be glacial, must from the outset arouse a certain suspicion, and the greater number of statements concerning glacial deposits at different levels in the palæozoic, mesozoic and tertiary epochs, might in the course of time come to have reference only to such totally non-glacial accumulations; or there might be errors in the determination of the ages of the beds, so that when really glacial formations occur they may be referable to but one or to very few horizons.

As I write this, an essay by Dr. Warth, which appeared in the second part of the Records of the Geological Survey of India for 1887, has come to hand, and brings the definitive proof that the four glacial horizons which R. D. Oldham maintained are all to be referred to one single level. The same thing will probably happen to the numerous glacial horizons which have been thought to be demonstrable in the Himalayas. On the one hand, they will probably prove to be mere boulder beds; on the other they will perhaps be reducible to one horizon that will approximate to the horizon of the Salt-Range.

Let us return to Europe, after this digression. We have seen that in the palæozoic formations of Europe there are no absolutely undoubted glacial formations except

in the Permian, but these stand above all doubt. The Permian glacial beds of England were described by Ramsay in a masterly way. They occur in the midland counties, and extend thence over very considerable areas and frequently attain to a thickness of several hundred feet. The blocks are either angular or half-rounded, and often from 3 to 4 feet in diameter. The surface of the greater number of them is smoothed, very many are perfectly polished and bear fine scratchings, which are either all parallel, or belong to different systems crossing each other at various angles. These boulders lie in a red marl and consist nearly all of Cambrian quartzite, of various Silurian rocks and of others of the upper Caradoc, and all must have been carried a distance of at least 20 to 40 English miles.

What place these breccias hold in the Pemian stratigraphical sequence is a little difficult to determine. Underlying them are sandstones and red marls which have yielded *Lepidodendra*, *Calamites*, and (?) *Strophalosia*, and which in their turn rest unconformably on the beds of the upper Carboniferous. The breccias are certainly of marine origin, and belong either to the middle division, or the lower section of the upper division of the Permian. Similar breccias have been pointed out in Ireland and Scotland.

We must thus assume, for a great part of the British Islands at least, at the time of the Middle or Upper Permians, glacial conditions under which the breccias in question were formed. Ramsay, it is true, believes that many also of the "Rothliegende" breccias on the Continent are of glacial origin, but nothing more has been made known about this. Here, however, another fact of great interest has to be taken into consideration; the fact, namely, that in all Europe the transition from the palæozoic to the mesozoic type of the floras, and the dying out of the greater part of the palæozoic plant types, occurs in the middle of the Permian epoch, and is thus again coincident in time with the glacial phenomena described from England. We see thus that in Europe also the thorough change of the flora goes hand in hand with the change in the climatic conditions.

From North America also boulder beds of similar age are cited, but it is not decided positively whether they are really glacial or not. It appears certain however, that at the time of deposition of the Permians a great part of the northern hemisphere was visited by a great depression of temperature. What had happened to the southern hemisphere, already in the upper coal-measure period, only befel the northern hemisphere in Permian times. In each case, however, the thorough change in the temperature conditions is also mainfested in the thorough change of the flora; and by the conditions obtaining in Europe we are led to the same conclusion as we expressed above with reference to the facts observed in the southern continent, that the carboniferous plant types must have been very delicate in their nature and unable to withstand severe frosts.

The Permian cold period in Europe does not, however, seem to have been limited to the northern hemisphere. If we turn to the tabular statament on page iii we see that in the Hawksbury beds in Australia, glacial conditions occur again. These beds should very probably be considered equivalents of our Permian; and thus we should have to note in Australia also a return of cold in Permian times. But here the cold has not acted so effectually; it met with a vegetable community which could endure it, and had previously in part experienced something of the kind, and in consequence we do not see any thorough change of the flora.

In India, traces of the younger carboniferous glacial period seem to be wanting. In the Salt-Range, the older very thick glacial deposits are overlaid by beds with *Fusulina longissima, Moll.*, and some other species, and these are followed by the rich Permian fauna described by me. This fauna is by no means an autochthonous one, for it consists of a community of organisms thrown together like dice in a variety of ways.

The greater part of the fauna emanates from the east from China, which had already in the upper Coal-measure period been colonized from America, as is clearly taught by the Lo Ping fauna described by Kayser. A colonization at such an immense distance can only take place under specially favourable circumstances and with the assistance of marine currents. It was these probably which made the climate of China so much milder that the formation of the coal-measures could continue uninterruptedly, while in the neighbouring India great ice-masses were being heaped up. These ocean currents extended in the Permian time as far as the Indian coast of the great southern continent, and by bringing warm waters with them caused there the rich development of organic life with which I became acquainted in the Productus limestone. From this source spring also the majority of the species of the Indian Permian. Another, but smaller number of them, indicates a connection with the carboniferous fauna of Australia. According to the observations of R. D. Oldham, the latter is embedded in the glacial deposits, and may well therefore be considered as a cold-water fauna. If regarded from this point of view; it is explicable why so few types of this fauna, of which indications occur in the glacial beds of the Salt-Range, have survived into the Permian deposits. A third almost invisible fraction of the fauna points to relations with the north (the lands of the Caucasus). But the richer the Permian fauna enclosed in the Productus limestone appears, the more remarkable does it seem that this fauna appears to be suddenly cut off without any transition forms, as soon as the first deposits of the *Ceratite* beds, that is to say, the lowest Trias, appear. This sudden disappearance of the palæozoic animal types in India brings us to another question that has yet to be discussed,—whether the great depression of temperature, which was followed by the above described glacial phenomena, and which showed as its immediate result the extinction of the palæozoic plant types, had also similar influence on the marine faunas, and caused the reduction of the palæozoic animal type to a small residue.

If we study the effect of the cold of the quarternary glacial period on the marine faunas, we see that an extinction of the types is not caused immediately, but that only a horizontal displacement of the faunas sets in, and they thus accommodate themselves in this way to the conditions of temperature.

So, also, in that long past time to which the above described glacial formations belong, the approaching cold will from the first have had that effect, and the several faunas will, from the first, have sought the places in which the conditions of temperature agreed with the conditions of life essential to them. But when in addition to the greatly lowered temperature another distribution of the great continental land-masses takes place, which is followed by a totally different distribution of the ocean currents, then a state of things will appear at many points of the earth's surface which offers no longer the life conditions necessary for a community of marine organisms accustomed to a high-water temperature, and they will have to perish wholesale,

so that only a small nnmber will be able to save themselves and reach a fresh period.

Such a case doubtless occurred in the Salt-Range, while, at the time of the second carboniferous cold period, warm currents flowing here from the east favoured a rich life; but this current was at the Permian period suddenly diverted and replaced by a cold current from the far north.

That this was really the case is proved by the enclosed fossils; for, with the lower beds appear suddenly Siberian cephalapoda types (*Siberites*, &c.) in great numbers. This marine current continued throughout the Triassic and Jurassic periods, and caused a deep descent to the southward of the boundaries of the Boreal marine province. For the Jurassic system, this descent was long since demonstrated by Neumayr.

Thus it appears that the possibility is not barred that the great revolution which occurred also in the fauna of the seas at the end of the palæozoic period, may be referred back, in part directly, in part indirectly, to the great depression of temperature which at the end of the palæozoic time appears to have spread itself over the whole earth, South America excepted.

As far as I know, South America is at present the only continental mass in which glacial formations have not been shown, either in the upper Carboniferous or the Permian.

The presence of a mild climate in this quarter is proven by the existence of coal-measures with genuine carboniferous plants in Brazil.

South America seems to have played a similar part during the carboniferous glacial period to Western North America in the time of the quarternary ice cap; where, as shown by Campbell, glacier traces are very sparingly present, and are restricted to the higher-lying parts of the country.

I have thus striven to demonstrate a glacial period which appeared with great intensity in the upper Carboniferous period on a continent the greatest part of which lay south of the equator; but which later in the Permian period extended itself over the greatest part of the globe. However many ice-made formations in earlier and later times have been mentioned in geological literature; at no time can such deposits be shown in such wide extension as in the Carboniferous [1] and the quarternary periods.

As far as our knowledge now extends, there appear thus to have been two great periods of cold which our earth has passed through up to the present; and of these the second seems to have been pretty nearly the counterpart of the first.

From my deductions, however, it becomes abundantly clear that in the earlier, as in the later, times, the distribution of the plant types on the surface of the earth was dependent on climatic conditions, so that plant remains can only be used as leading fossils under certain restrictions and precautions.

To enter upon the causes of the great depression of temperature in the Carboniferous period, is not in the very least my intention. Endless studies will yet have to be made ere any degree of clearness will be attained to in this respect. I would

[1] When I speak here of the carboniferous in general, I reckon the Permian as a sub-division of the Carboniferous. I do not at all believe that the Permian can maintain itself as an independent system.

only mention that the explanation indicated by R. D. Oldham in the Geological Magazine for 1886, and before that in the Journal of the Asiatic Society of Bengal, appears to me quite insufficient, as the conditions are certainly much more complicated than pre-supposed by that attempt at explanation.

The Sequence *and* correlation *of the* Pre-Tertiary Sedimentary formations *of the* Simla Region *of the* Lower Himalayas, *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.*

Since the publication of the *Manual of the Geology of India,* there has been no general review of our knowledge of the geology of the Himalayas, yet so great has been the progress made since then, that it becomes daily more necessary that the many isolated accounts of different portions of the Himalayas should be amalgamated, so far as is possible, and a starting point for further work obtained.

As long as the survey of the Himalayas is in active progress, the individual workers are naturally loth to publish anything which, having the appearance of finality, would perhaps be superseded by the next season's work: but as my own work in the Himalayas, which has been interrupted for some time, may be suspended owing to more pressing demands made on the Geological Survey, this will give an opportunity for publishing a summary of the present state of our knowledge of the region with which I am personally acquainted.

Owing to the many interruptions of my work in the Himalayas, it is impossible for me to give a detailed account of the geology of the Simla Region, and I shall consequently confine myself to giving an account of the sequence which will be useful as indicating systems which have been identified in the region under consideration, of which equivalents may be looked for in other neighbouring regions.

"Central gneiss" series.

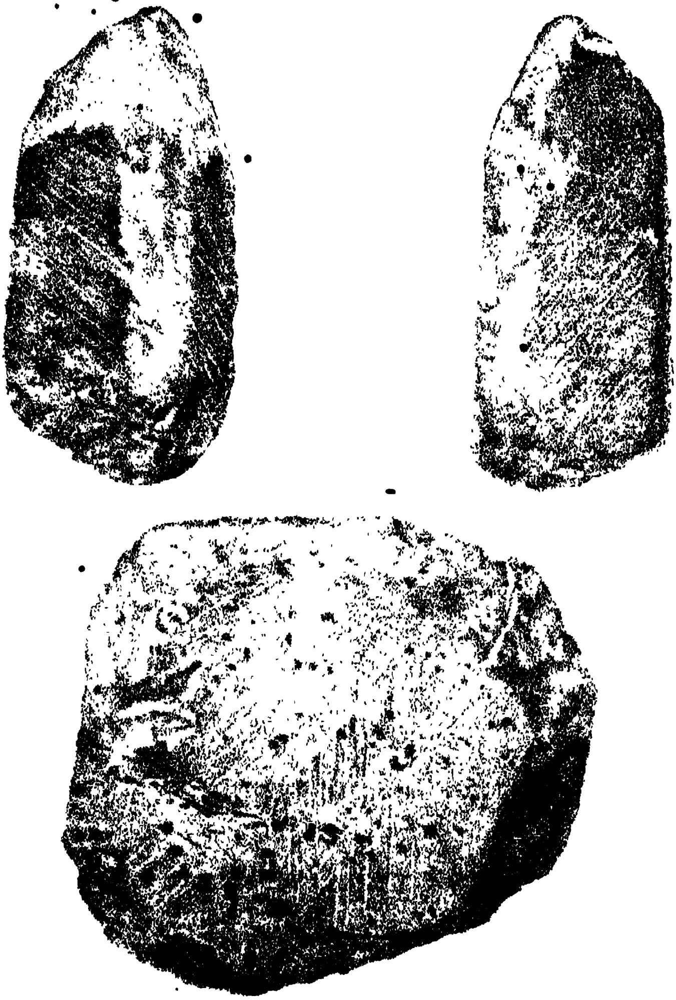
Within the limits of the Simla Region, by which is here meant that part of the Lower Himalayas which lies west of the Jumna river, the oldest series of rocks consists of bedded gneiss. The occurrence of gneiss in the Himalayas was noticed by the earliest observers, but it was first separated as a distinct system by Dr. Stoliczka, who named the gneiss, seen by him on the Babeh pass, the "Central gneiss"[1] from an idea that it formed the original axis or core on either side of which the sedimentary beds of the Himalayas were deposited.

Though the hypothesis on which this idea depended is no longer tenable, and the name, in so far as it implies a theory, inappropriate, yet as this theory has been abandoned by geologists the old name may safely be maintained as preferable to Laurentian or Archæan, both of which imply an hypothesis there is no means of verifying.

Babeh pass section.

The Babeh pass section does not strictly belong to the Lower Himalaya but is so close to the ill-defined boundary of this region that it will be considered here. On the ascent from the Sutlej river

[1] Mem. Geol. Surv. Ind., V, pt. i.



Polished and scratched pebbles from the Boulder bed, Chel Hill, Salt Range.

at Wangtu bridge an apparently continuous sequence of not less than 11,000 feet of gneiss is seen dipping at high angles to north-north-east. The rock varies in texture and composition a few thin bands of mica schist being seen, but for the most part it is a massive, often granitoid, gneiss; in some of the beds the foliation is absent or obscure and these generally contain porphyritic crystals of orthoclase, twinned on the Carlsbad type. The foliation is parallel to the bedding planes and the successive layers, varying in thickness from a few inches to a few feet, differ from each other in texture and mineral composition; showing that, whether metamorphosed from ordinary sediment or not, the rock was originally formed by some process analogous to, if not identical with, ordinary sedimentation.

Exposure at head of Pábar valley.

Beds belonging presumably to the same system, though differing somewhat in mineral character are exposed in the upper part of the Pábar valley in Bissáhir.[1] Here there is a much larger proportion of very slightly felspathic mica schists and quartzites, some of the latter being perfectly free from felspar and showing their detrital origin very distinctly; on the other hand some of the beds are almost pure orthoclase. None of the beds of gneiss are as highly metamorphosed as the generality of those on the Babeh pass section, but *augen* gneiss is abundant; in some of the beds lenticular masses of felspar over an inch thick and about three in length are scattered through the rock, the internal structure being in all cases that of a crystal twinned along a plane passing through the edge of the lens and lying parallel with the planes of foliation.

Possibly two series.

In spite of the differences between the gneiss of the Pábar valley and that of the Babeh pass I have thought it best, in the absence of any proof to the contrary, to class them together; the occurrence of *augen* gneiss in both and the fact that the most common accessory minerals are schorl and garnet in both cases, is to a certain, though slight, extent, confirmatory of this conclusion.

The central gneiss appears to occupy but a very small area within the Simla Region as here defined but it attains a great development in the Central Himalayas.

The Jaonsár system.

Next following the central gneiss comes what I shall call the Jaonsár system. This was first identified by me in the district of Jaonsár; it was named the Chakrata series,[2] and divided into an upper and a lower group. But subsequent examination of the same system where it is more satisfactorily exposed, west of the Tons, has led me to the conclusion that it should be divided into three divisions, the lowest of which was, through a mistaken correlation, erroneously classed with the uppermost.

Lower Jaonsár sub-division.

Of these three divisions the lowest consists of a great thickness of grey slates containing, towards the upper limit, a band of blue limestone about 300 feet thick. They have not been fully examined and it is not even certain whether they really belong to this system or no.

Jaonsár quartzites.

The middle division of the Jaonsár system is characterized by the prevalence of red quartzites and slates It forms the hill on which the sanitarium of Chakrata is built and there consists of purplish red slates and quartzites, the latter not infrequently mottled with white.

[1] For description see Rec. Geol. Surv. Ind., XX, 160.
[2] Rec. Geol. Surv. Ind., XVI, 93

Unconformable to central gneiss.

The same purple quartzites are found in the Naira[1] and Bangál valleys of Eastern Sirmur, and at the head of the Pábar valley the gneiss series is unconformably overlaid by purple quartzites and slates, above which come hornblende schists, probably representing the volcanic beds of the upper group.

Upper Jaonsár.

The beds of the upper Jaonsár group are exposed in the northern part of Jaonsár Báwar, but their relations to the quartzites are better shewn in the Bangál valley in Eastern Sirmur, on the southern side of which the red quartzites and slates of the lower group are overlaid by about 200 feet of dark-grey felsitic trap covered by as much more of mixed trap and volcanic ash. This does not, however, exhibit the whole thickness of the volcanics, as their upper part is cut off by an unconformity.[2]

The volcanic beds of Northern Jaonsár differ from these in some respects; lava flows are rarer while ashes, interstratified and mixed with sub-aqueous sediment are abundant, moreover a band of limestone, some 300 feet in thickness is interstratified in the series.[3]

An old land area.

This difference is due to a difference in the mode of origin; while the volcanics of Jaonsár were certainly deposited under water, those of the Bangál valley were of sub-aerial origin. At one place a layer of pebbles, some of lava but mostly of vein quartz, was found interstratified with the volcanics.[4] The presence of lava pebbles would not prove more than the contemporary existence of a volcanic island, but the quartz pebbles point to the proximity of an area of non-volcanic rocks, whose shores must have bounded the sea area of the Jaonsár period.

Possible newer group.

On the northern side of the Bangál valley these volcanic beds are overlaid by a great thickness of sub-schistose slate, but whether it belongs properly to the Jaonsár system or a newer one is not known.[5]

Boulder-bearing beds.

Before leaving this system I must mention that a conglomeratic bed, similar to that of the Blaini group, to be described further on, has been recorded in two distinct localities, and in both cases low down in the section. The most westerly of these is on the north side of the Bangál valley. Here at the eastern boundary of the Jaonsár system, where it is faulted against the Deoban limestone, there occurs a bed of semi-schistose red quartzose slate, through which are scattered rounded boulders of hard crystalline quartzite. The position of this bed in the section is a little doubtful as the rock was not seen *in situ* but the position in which the detached fragments were found and the similarity between the matrix and some of the beds of the Lower Jaonsár group, alike indicate that it occurs low down in that system of rocks. It is important to note that the bed cannot be of volcanic origin, as is proved by the rounded, water-worn form of the boulders; and that it is not associated with any volcanic beds, being separated by between 2,000 and 3,000 feet of sedimentary beds from the upper Chakrata traps.[6]

[1] Neweli of Atlas of India.
[2] Rec. Geol. Surv. Ind., XX, 157.
[3] *Ibid.* XVI, 193 (1883).
[4] *Ibid.* XX, 157.
[5] R. D. Oldham, MSS. Report.
[6] R. D. Oldham, Rec. Geol. Surv. Ind., XX, 157 (1887), and MSS. Report.

A somewhat similar bed occurs in Northern Jaonsár, where it has been recorded as Blaini. Here the matrix is quartzite and the included fragments are angular, this combined with the presence of volcanic beds among the quartzites with which it is interbedded renders it impossible to declare that the rock is not of volcanic origin.[1] This hypothesis does not, however, seem to me to fit the case, and it is certainly equally probable that it is of the same age and origin as the Bangál rock. What may have been the origin of the latter I shall not at present discuss.

Deoban system.

Above the Jaonsár volcanics there is, in Northern Jaonsár, a great development of limestone which forms nearly all the higher parts of the group of mountains running north from Deoban. This limestone was at one time regarded as the equivalent of that seen on the Krol mountain, south of Simla; but was named Deoban limestone[2] by me in 1883 in consequence of a doubt as to the correctness of this identification. Subsequent investigation has shown that the two limestones are distinct, so the provisional name may stand. The unconformity of this system to the Jaonsár beds is very plainly seen in Northern Jaonsár and is especially well-marked in the valley of the Dhára gadh where the occurrence of a band of limestone among the beds of the Jaonsár system serves as a horizon to mark the oblique truncation of the beds of the older series by the contact surface between them and the Deoban limestone.

The Deoban system as seen in Jaonsár consists of a pale grey, bedded limestone, with a varying proportion of dolomitic beds and intercalated slates. The limestone is frequently mephitic, in places contains cherty concretions, and is occasionally oolitic. A speckled limestone shewing black specks on a white ground is common and some of the beds exhibit a peculiar pseudo-organic structure which gives them the appearance of being composed of a mass of closely chambered shells; curiously enough these apparent fossils are generally imbedded in a matrix which weathers brown, while they retain their blue-grey colour.[3] The structure is possibly of organic origin, but if so, it is impossible to guess even the family of the animal that produced it, and if of purely concretionary origin it is strange that it should be found over so large an area. I have found it in Sirmur, west and south of the Giri, and a precisely similar structure was described, and illustrated, by Dr. McClelland, in the "transition" limestone of Kumaon.[4]

This system is not known with certainty to occur away from the Deoban exposure, but it is almost certain that some of the exposures of limestone south-east of the Chor should be ascribed to it, while the great limestone of the Shali peak, north-east of Simla, probably belongs to the same system.

The carbonaceous system.

Following on the Deoban there comes a system which I find some difficulty in treating satisfactorily. It probably occupies a more extensive area in the north-western termination of the Lower Himalayas than any other system of beds, but all the

[1] Rec. Geol. Surv. Ind., XVI, 193, (1883).
[2] Rec. Geol. Surv. Ind., XVI, 195.
[3] Loc. cit.
[4] Jour. As. Soc. Beng., III, 628, plate XXXV, fig. 4 (1834), see also Geol. Mag., 3rd Decade V, 255 (1888), where a similar structure from the limestone of Kulu is described, and considered as of organic origin.

sections examined as yet shew individual peculiarities, and as it is impossible to say where the system is best exposed I am driven to take a descriptive name from the slates impregnated with carbonaceous matter which characterize its upper portion, and I shall speak of it as the carbonaceous system.

Sub-divisions, Simla slates.

On the Simla section the lowest group seen consists of a great thickness of grey slates, gritty slates and quartzites, being the Infra-Blaini or Simla slates of Mr. Medlicott.[1] It is not absolutely certain whether these slates do or do not belong to the carbonaceous system, but in the neighbourhood of Simla there is no indication of an unconformity and for the present it is best to class them here.

Blaini group.

Following on the Simla slates comes a very peculiar group of beds, originally described by Mr. Medlicott, under the name of Blaini, as follows:—[2]"The principal rock of this little group is a pure limestone, very dense, ometimes compact sometimes sub-crystalline; its commonest colour is pale pink, but often blue and greenish-yellow; it occurs in thin, well-defined layers, but these are often agglomerated together into one mass, the beds shewing only as bands in this mass.* * * It has a constant companion, more peculiar than itself, and the two combined furnish an unmistakable clue. This other rock is a kind of conglomerate. It occurs, I believe, below the limestone, though in the many inverted contortions it often appears above. The base of this conglomerate is a fine, gritty slate, of a dull green or blue colour, in fact altogether like the thin-bedded rocks in the midst of which it occurs. Through this base pebbles of quartz are thinly scattered, seldom larger than a hen's egg. These pebbles are sometimes so scarce as to pass unnoticed without special search. In most places sub-angular fragments of a *slate* rock are the prevailing foreign elements in the conglomerate, which thus assumes a very brecciated aspect."

With regard to this description I must remark that there seem to me some objections to the application of the word "conglomerate" to such a rock as is described. We require some term that indicates the occurrence of pebbles scattered through, and separated from each other by, a slate matrix, a structure which involves some special mode of formation and deserves a special name. But it is necessary to choose one that does not involve a theory, and perhaps the best name that can be applied is "boulder slate," on the analogy of "boulder clay," meaning thereby a slate containing scattered fragments of foreign rock, irrespective of the actual size of these fragments. An objection to the term is, of course, that indirectly it implies a theory, the term boulder clay having become almost synonymous with glacial; this objection may be held to be of less weight, as the theory implied is the only one that satisfactorily accounts for the known facts and, in any case, there is no essential or direct connection between the term used to describe the effect and the assumed cause. I shall therefore use the term "boulder slate" as meaning a slate which encloses boulders or pebbles of some older rock, and without reference to the theoretical origin of the rock.

The Blaini group, in the form originally described, has a tolerably extensive dis-

[1] Mem. Geol. Surv. Ind., III, pt. ii, p. 33.

[2] *Op cit.* p. 30. The name was originally spelt Blini, but the more correct spelling Blaini is now generally adopted.

tribution, being found even east of Mussoorie, but as a rule the boulder slates are more extensively developed, and the limestone, even in the neighbourhood of Simla, is by no means a constant member.[1]

Carbonaceous division.

Above the Blaini group, and intimately associated with it comes the series of beds from which I have derived the name of the system. They were originally described by Mr. Medlicott as "Infra Krol" from the fact of their occurrence underneath the Krol limestone on the Krol mountain. The series is there only partly exposed and this as well the suggestion of association with the Krol limestone might be held to necessitate supersession of the name, but it has held its own for 30 years in the Survey publications and it will be best to retain it, but in a more extended sense as including the "Krol quartzite." On the Simla hill the series consists of two bands of slates and limestones more or less impregnated with carbonaceous matter, separated by about 1,000 feet of schistose quartzites and garnetiferous mica schist. These last, which have been described as "Boileauganj quartzites," most probably represent the "Krol quartzite" of Mr. Medlicott—a term I shall discard as the beds described under it appear to belong to the carbonaceous system rather than to the Krol limestone.

Volcanic beds: carbonaceous division.

In the Simla section there is no trace of volcanic activity if we except some hornblende schists occupying the summits of Prospect and Jako hills at Simla, but elsewhere, in Jubal and Bisahir,[2] volcanic beds are everywhere found in the upper part of the series. They consist of ash beds, more or less mixed with ordinary sediment of detrital origin, and lava flows; the latter have not been examined in detail but appear to be for the most part basalts, more or less altered by subsequent change, frequently amygdaloidal but as often exhibiting no indications of a scoriaceous structure. In the recorded sections they are always interstratified with sediments and the ashes are more or less impure, showing that they were formed by submarine eruptions, though the actual vents may in some or all cases have been raised above the sea-level.

It may be noted that the distinctness of these volcanics from those of the Jaonsár series is marked not only by their position in the sequence, but by the much more basic type of the rocks they are composed of.

The different sections do not agree as to the position of the volcanic beds in the series. At Simla the hornblendic rocks are in the upper carbonaceous band. In the Sutlej valley they appear to occur both above and below as well as interstratified with white quartzites like those above which they occur on the Lambatách ridge. In the Deora valley of Jubal their position is doubtful and on the eastern flank of the Chor they seem to occur near the top of the lower carbonaceous band. The general conclusion that may be arrived at is that the volcanic beds do not belong to any fixed horizon but occur with greater or less vertical extent throughout the upper part of the Infra-Krol series, and always, so far as is known, well separated from the boulder slates of the Blaini group.

[1] See Rec. Geol. Surv. Ind. X p. 204 *et. seq.*, XX, p. 158.

[2] Rec. Geol. Surv. Ind. XX, 159; the volcanic beds of the Sutlej valley described by Col. McMahon also belong to this division. See Rec. Geol. Surv. Ind., XIX, 65, *et seq.*

Carbonaceous series of the Lambatách ridge.—On the Lambatách ridge, which rises north of the Tons, immediately above its junction with the Pábar, and in the north of Jaonsár-Báwar the carbonaceous series assumes a peculiar form. In the valley of the Koti gádh (Kunjado river) there is a series of coarse-grained foliated arkose rocks. Owing to the presence of large fragments of orthoclase and to the subsequent foliation of the rock it is difficult and often impossible to distinguish a hand specimen from some forms of the intrusive gneissose granite, but in the field there is little difficulty in telling the two rocks apart, not only does the arkose decompose more readily than the granite, but on looking over a weathered surface it is not difficult to find small pebbles. At a little distance, however, the huge rounded masses of the arkose are easily mistaken for an outcrop of granite.

Above this coarse-grained arkose there come foliated beds containing granules of felspar, which pass upwards into a coarse-grained felspathic quartzite or grit full of small granules of undecomposed felspar. In this rock pebbles and boulders ranging to over a foot in diameter occur, not heaped together, but scattered through the matrix of grit. The whole of the beds up to this are characterized by containing numerous granules of blue quartz. Above the conglomeratic grits come fine grained quartzites which extend across the Tons and were described by me as the Báwar quartzites;[1] they are semi-transparent where undecomposed but weather opaque white and ultimately into a very fine, sharp, white sand, owing to the decomposition of the felspathic cement; above these come volcanic beds and above them carbonaceous slates and limestones.

The conglomeratic grits above mentioned are, to say the least, not incompatible with a glacial origin; while it is difficult to understand how either gneiss or granite could have disintegrated without decomposition of its constituent minerals except under a severe climate. This combination of beds, indicating a period of exceptionally cold climate, overlaid by carbonaceous slates and limestones associated with volcanic beds seems to join these beds to the carbonaceous series, while, as an additional proof, schistose beds, characterized by the presence of granules of blue quartz are largely developed in connection with carbonaceous slates in the hills west of the Pábar river.

Mandháli beds of Jaonsár.

There remains for consideration a group or series of beds distinguished by me in 1883[2] as the Mandháli series and classed as distinct from the Blaini group. The group, as I now prefer to call it, is of the most protean character, consisting of quartzites, slates, limestones, conglomerates and boulder beds in most variable proportions and interstratified in the most extraordinary manner; it being not uncommon to find slates or even limestone interbedded with coarse grits or conglomerates This variability appears to be due to the fact that it has been deposited in close proximity to land, and always contains a large proportion of debris derived from the older rocks of the neighbourhood. Thus in Northern Jaonsár and Báwar, where it rests on the Deoban limestone fragments of that rock are extremely abundant in it and there are several beds of a conglomerate composed exclusively of rounded boulders of the Deoban limestone imbedded in a matrix of the same rock in a finely comminuted

[1] Rec. Geol. Surv. Ind., XVI, 197.
[2] Rec. Geol. Surv. Ind., XVI, 196.

form, while in Southern Jaonsár, where it rests on the quartzites of the Jaonsár series the group consists almost entirely of coarse quartzites and grits.

But the great characteristic of the Mandháli group is the presence of boulder beds of the same type as that of the Blaini group. So great indeed is the similarity that in more than one case an exposure of this group has been described as Blaini.

In Jaonsár the Mandháli group appears to be completely isolated and the rocks occurring next above it removed by denudation,[1] but on the eastern flanks of the Chor mountain at the head of the Minas gadh (Suinj R. of Atlas of India) and east of Chepál in the Jubal State beds shewing the same characteristics as the Mandháli group rest unconformably on a massive limestone, fragments of which they contain. The limestone is similar in character to the Deoban limestone of Jaonsár, with which it is, moreover, continuous at the surface; and the beds overlying it may be taken to represent the Mandháli group of Jaonsár. But these last underlie, apparently with perfect conformity black carbonaceous slates which again underlie a great thickness of quartzites and schists undistinguishable from the Boileaugunj quartzites of Simla.

Identity of Blaini and Mandháli.

This section would seem to indicate the indentity of the Blaini and Mandháli beds, a conclusion further supported by the peculiar and exceptional character of both and the occurrence of recognizable Blaini beds both east and west of Jaonsár, where, with the exception of the Mandháli beds they are unrepresented. If we take the glacial origin of the two as proved, this in itself would establish the contemporaneity of the two groups of beds which outside evidence places between the Deoban and the upper part of the carbonaceous system. The only indication of their separation lies in the fact that when examining Jaonsár in 1882-83 I separated the Mandhális from the Báwar quartzites which are here classed with the carbonaceous system. But the separation was based on the difference in disturbance of the two groups, a difference which subsequent experience has shewn me might well be due to the superior homogeneity and massiveness of the Báwars.

The Krol system.—Above the beds of the carbonaceous series there is, on the Simla section, a limestone series described by Mr. Medlicott as the Krol limestone, owing to its forming the upper part of the mountain of that name rising over the cart-road to Simla. According to him the limestone may be divided into an upper and a lower portion, the distinguishing mark being a greater preponderance of shaly beds in the lower half, though a perfect transition is stated to occur between them.

Like the Deoban the Krol is a blue limestone with frequent concretionary masses of chert. The lithological similarity is so great that they might be and have been taken for the same series, but the superposition of the one and infraposition of the other to the carbonaceous series leaves no room for doubt that they are distinct.

The Krol limestone extends south eastwards from the Krol mountain to the eastern borders of Sirmur, and in Jaonsár there occurs a newer limestone, sometimes resting directly on the Deoban sometimes with the intervention of beds of the Mandháli group, which can hardly but be the Krol.

[1] Rec. Geol. Surv. Ind., XVI. 196.

Mr. Medlicott regarded this limestone as conformable to the underlying beds, but the great variations, in the thickness of the Krol quartzite, as recorded by him, and the total absence of the great thickness of quartzites and upper group of carbonaceous beds seen on adjacent sections, point very strongly to an unconformity. If the upper limestone of Jaonsár is Krol, and it can hardly be anything else, the unconformity is unquestionable for the whole thickness of the carbonaceous series is there wanting.

As yet neither upper nor lower members of this group have been determined, though it is hardly credible that the whole sequence should consist of only a few hundred feet of limestone with shales towards the base.

A sequence of marine beds.

Such is the sequence in the Simla Himalayas as far as it has at present been determined, and throughout this vast thickness of rocks not a single fossil has been found, if we except the peculiar organic-looking structures found in the Deoban limestone, yet there can be little room for doubting that they are principally if not entirely of marine origin. The hypothesis that they may be of fresh water origin has been proposed to account for the absence of fossils, but it has never been strenuously upheld and appears to be inconsistent with the vast thickness of some of the systems or with their uniformity over an area much larger than that described as the Simla region of the Himalayas.

Only two attempts have been made to correlate the rocks of other parts of the Himalayas with those of the Simla region, one by Dr. Stoliczka in 1865, and the other by Mr. Lydekker in 1883; but since both were ignorant of any more extended sequence than that contained in Mr. Medlicott's memoir, it is not necessary to refer to them in detail.

Correlation dependent on physical characters.

As no fossils have been found in any of the rocks of the Simla region, it will be necessary to depend on the physical characters of some of the groups. Their mere lithological similarity is well known to be valueless for the identification of rock groups unless applied within a very limited area and over very short gaps. A sequence of groups each shewing certain lithological characters is more important, and where a similar sequence of similar rocks is found greater weight attaches to it than to the mere lithological similarities of single groups. But even this would fail when applied over such distances as we have to deal with.

The reason for this is easy to find, and lies in the fact that conglomerates, sandstones, shales, limestones, and any gradation between them have been forming at every period of the earth's history, since it cooled down sufficiently to allow of life, and that the formation of any particular variety of deposit at any particular place and time depends on the accidents of current, depth, and distance from shore. But the same objection does not apply to those characters which are the result of causes which act intermittently at long-separated periods and independently of the accidents which control the nature of ordinary sediments.

Prominent among such would be the traces of a glacial period which we might expect to find wherever sediment was being formed on the sea bottom.

Of less value would be the occurrence of beds of volcanic origin, for though seldom if ever confined to a single locality, volcanic energy generally begins slowly,

lasts long and is apt to recur in localities not far separated from each other at intervals which, geologically, are not of great duration.

Of similar nature may be the peculiar impregnation with carbonaceous matter seen among the shales of the carbonaceous series, for in other parts of the Himalayas similar beds are found and everywhere, so far as is known, confined to a single group in the sequence.

Carbonacecus system.

Among the many systems in the sequence of the Simla-Himalayas, the carbonaceous system exhibits all three of the special peculiarities noted above and we may consequently expect to recognize it with comparative certainty in other regions where it may exist. Among these that which most naturally comes first is the Kashmir area where the rocks more nearly approach those of the Simla region in character than do those of the Central Himalayas.

In the Cashmere region Mr. Lydekker[1] divided the sequence of pre-tertiary rocks into three systems :—

3.—The Zánskár system.
2.—The Panjál system.
1.—The Metamorphic system.

These three systems are described as not only conformable in themselves but are spoken of as conformable to each other; the metamorphic system is regarded as palæozoic (Cambrian) while the newest beds of the Panjál system are Cretaceous. Such an enormous conformable sequence of rocks, stretching from early palæozoic to latest secondary times, is not only in itself unusual but is directly contrary to what we find to be the case in other parts of the Himalayas; and it becomes necessary, in consequence, to enquire into the grounds it is based upon.

The metamorphic system is regarded as composed of gneiss of two distinct ages, one archæan, the other composed of metamorphosed beds of Panjál age. This is not in itself impossible, for, though the general tendency of modern geologists is to regard a gneiss series as necessarily older than a slate series, it is by no means proved that slates are never metamorphosed into gneiss. But the facts detailed by Mr. Lydekker do not necessitate this conclusion; he confessedly does not distinguish between the true central gneiss and the gneissose granite, both are indicated by the same colour on the map and described together in the same chapter without being specifically distinguished,[2] and what he has described as partial metamorphism of the Panjál rocks into gneiss seems to be more properly described as intrusions of gneissose granite in the Panjál slates. The error is one which, owing to the tendency of the granite to be intruded in sheets parallel with the bedding and the highly foliated structure it usually assumes under those circumstances, has been fallen into by more than one observer previous to Mr. Lydekker.

"Panjál system."

The Panjál system is used as a generic term for "all the rocks below the Kuling series, and above the metamorphics." As might be expected from this comprehensive definition, the different sections

[1] Mem. Geol. Surv. Ind., XXII, (1883).
[2] Mem. Geol. Surv. Ind., XXII, chap. IX.

described vary widely among themselves. What may be called the type section, that across the Pir Panjál range is described as consisting of—

1. Greenish slates and sandstones with amygdaloidal traps.
2. Black and green slates with thick beds of conglomerate, containing pebbles of quartzite and slate.
3. Whitish quartzites and sandstones.
4. Black schisty slates with pebbles of gneiss and quartzite.[1]

It is further stated that "the resemblance of some of the rocks of No. 2 to the lower division of the Blaini series, both petrologically and stratigraphically, cannot fail to be noticed:"[2]

Panjal traps.

The volcanic beds No. 1 are largely developed in Kashmir and Mr. Lydekker is probably right for the most part in classing them all of one age. The occurrence of volcanic beds at two distinct horizons in the Simla region does not necessitate both of them being represented in Kashmir, and the only indication of two distinct volcanic series that I can find is in the description of the section on the road from Kashmir to the Kishenganga valley over the Tútmári pass where the volcanics are said to occur at a lower horizon than in the Kashmir valley.[3]

In the neighbourhood of the Kashmir valley there is a perfect conformity between these traps of the "Panjal system" and the overlying Kuling series at the base of the "Zánskár system," or to speak more correctly, the volcanic outbursts continued well into the Kuling period.[4]

Kuling series.

The rocks of the Kuling series consist of limestone quartzite and shale or slate, the former appears to be more abundant in the Kashmir valley than elsewhere, while the latter is often impregnated with carbonaceous matter like the slates of the carbonaceous series in the Simla region. It has yielded a series of fossils, limited in number, but still enough to fix its homotaxis with the lower Carboniferous rocks of Europe.

Probable unconformity above the Kuling.

The conformity between the Kuling and supra-Kuling series appears to have been assumed rather than proved; indeed, Mr. Lydekker's description has several passages which point to the opposite conclusion. The supra-Kuling beds are described as resting, at more than one point directly on the Panjal traps without the intervention of the Kuling beds, but in respect to this he says that wherever it occurs he has concluded that "the Kuling series has been included in the trappean rocks and cannot consequently be recognised as a distinct formation."[5] But it is equally open to conclude that it indicates an unconformity, and this conclusion is supported by the fact that both in Spiti and in Hundes an uncomformable break occurs between the Carboniferous and Triassic beds.

Supra-Kuling.

The supra-Kuling beds of Kashmir appear to consist almost entirely of massive limestone and dolomite which have yielded some fossils, for the most part, unfortunately undeterminable specificially

[1] Mem. Geol. Surv. Ind., XXII, 216.
[2] Similar beds occur in an analogous position below the volcanic beds in the Sind valley and on the slopes of the Hóksar range east of the Kashmir valley.
[3] Mem. Geol. Surv. Ind., XXII, 225.
[4] ,, ,, ,, ,, ,, 135.
[5] ,, ,, ,, ,, ,, 148.

but indicating the triassic age of the lower portion of the series. It is very probable that on more detailed examination this series will have to be split up into more than one and will certainly be sub-divided into groups.

With the third sub-division, or Chikkim series, which is represented only by a couple of isolated patches, we have no present concern.

From the above it appears that Mr. Lydekker's division of the beds above the gneiss, into two systems, is not a natural one and it is extremely probable that a more detailed examination of the country will result in an amplification of the sequence similar to that which has taken place in the Simla-Himalayas.

Carbonaceous system represented.

One point, however, seems clear, that there is in the Kashmir area a conformable series of beds charactized by the occurrence of: (1) boulder-bearing slates of non-volcanic origin, (2) at a higher horizon copious indications of contemporaneous volcanic activity, and (3) the occurrence of beds remarkable for the prevalence of carbonaceous matter. The similarity between the boulder slates and those of the Blaini group in the Simla-Himalayas has been especially remarked, and similar beds are found in the intermediate country of Chamba; while the resemblance between the volcanics of Cashmere, of Chamba, and of the Sutlej valley, the last of which belongs to the carbonaceous series, has been remarked upon by Colonel McMahon.[1]

These coincidences can hardly be all of them fortuitous and the conviction naturally forces itself upon one that the series of rocks referred to above is the equivalent of the carbonaceous series in the Simla-Himalayas; and the conclusion becomes irresistable when we compare the latter with the Kuling series in Spiti.

Kuling series of Spiti.

The series of rocks named Kuling by Dr. Stoliczka[2] is exposed in the only localities that have been visited as yet, at the bottom of a valley: the whole thickness is not seen and they are moreover very much disturbed. The beds, however, consist of quartzites and black carbonaceous slates similar to those of the carbonaceous series, and at two spots in the Spiti valley pebble-bearing slates, precisely similar to those of the Blaini group have been found, one of these being certainly among the Kuling beds. No beds of volcanic origin have been found but this may only be due to the imperfect exposure of the section.

Here, again, the coincidences can hardly be entirely fortuitous and we are justified in accepting Dr. Stoliczka's identification of these beds with the carbonaceous, or as they were then styled Infra-Krol, beds of the Simla area. In a similar manner the Kuling beds of Spiti and Kashmir might be safely correlated on the ground of their physical characters alone; but in this case we have the confirmatory evidence of fossils, four out of the seven species found in Spiti having also been found in the Kuling group in Kashmir.[3]

[1] McMahon. Rec. Geol. Surv. Ind., XVIII., 97, 98, and XIX, 68.

[2] Mem. Geol. Surv. Ind., V, pt. i.

[3] The three localities mentioned in the text probably do not by any means indicate the limits of the area over which the carbonaceous system maintans its uniformity. In the neighbourhood of Naini Tal carbonaceous slates, conglomeratic slates and volcanic beds, are developed largely, and will probably prove to belong to a single system when fully examined.

Homotaxis of the carbonaceous system.

Having established the presence of beds belonging to the carbonaceous system in Kashmir and Spiti, we may now proceed to the consideration of the homotaxis indicated by the fossils that have been found in these districts.

Classed as lower Carboniferous, but probably newer.

The fauna[1] comprises 46 species in all, of which 17 are also found in the lower Carboniferous of Europe, 12 in the marine Carboniferous beds of Australia, and 16 in the Productus limestone of the Salt-Range. From the above it has been concluded that the genaral homotaxis is with the lower Carboniferous beds of Europe; but there are good reasons for considering the beds as newer than this.

In the first place the relationship of the fauna to that of the Productus limestone is close though not sufficient to establish contemporaneity considering the small intervening distance; moreover, the identities being among the more characteristically palæozoic forms of the Productus limestone fauna is compatible with an earlier date of formation. On the other hand, the Productus limestone of the Salt-Range is, like the Kuling group of Kashmir, underlaid by a conformable sequence of beds at the base of which occur boulder shales of generally acknowledged glacial origin. These doubtless are the equivalents of the boulder-bearing slates of Kashmir and Simla and of contemporaneous origin with the latter. In view of this, and of the known variations in the marine fauna of neighbouring localities due to variations of environment, I think far greater weight should be attached to the similarity than to the differences between the two faunas and they may consequently be regarded as homotaxial, if not of contemporaneous origin. In this case the age should be determined by the more extensive fauna, that of the Productus limestone, which has been regarded by Dr. Waagen as of Permian age, a date which, in view of the presence of so typically mesozoic forms as *Ammonites*, we may safely regard as the oldest admissible date.

Further evidence pointing to the same conclusion is the occurrence in the glacial beds below the Productus limestone of fossiliferous pebbles[2] of derivative origin which have yielded a limited fauna closely allied, so far as it goes to that of the marine Carboniferous beds of Australia. There can be little doubt that the beds, from which these fossiliferous pebbles are derived, are the equivalent of the Tálchir group in the Peninsular area, and I have elesewhere given my reasons for regarding the latter as the equivalent of the marine Carboniferous beds of Australia, and not as the Salt Range pebbles would indicate of later age. The Tálchirs, I need hardly add, are now generally regarded as of uppermost palæozoic, probably Permian age.

From the above it will be seen that the fauna of the Kuling group can be made to indicate a homotaxis anywhere between the lower Carboniferous and Permian horizons of Europe. This is a good instance of the limits of error necessarily attaching to the palæontological method when applied over long distances; but enables us to arrive at the conclusion that the carbonaceous system of the Him.

[1] See Lydekker. *Mem. Geol. Surv. Ind.*, XXII, 158.

[2] The strictly pebbly condition is open to question, see R. G. S. of I., XX, 118, and Dr. Waagen's Essay on "The Carboniferous Glacial Period," in present number, p. 118, which should be read in connection with the whole of this paragraph.—*Ed.*

layas was deposited during the latter end of the palæozoic period, and corresponds to part, if not the whole, of the Carboniferous and Permian eras.

The Jaonsár system.

The only other system which I can correlate with any degree of certainty is the Jaonsár system, the lower group of which is probably represented by the middle division of the Babeh series of Dr. Stoliczka. The lithological resemblance of the groups is most striking and though no volcanic beds are seen in the Babeh pass section they are described by Dr. Stoliczka as occurring in Lower Spiti.

Equivalent to Vindhyan.

In the Peninsular area it may be represented by the Vindhyan system, the rocks of which would, if more indurated and disturbed, resemble those of the Jaonsár system. A further piece of evidence though not at present of great value, is the occurrence of beds of possibly glacial origin at the base of the Jaonsár system and the occurrence of beds containing large boulders imbedded in a fine-grained matrix among the Vindhyan beds east of the Aravalis, and the occurrence of similar beds at the base of a series of rocks, occurring west of the Aravalis, which have been, with little or no hesitation, classed as Vindhyan by every observer who has examined them.

Of Silurian age.

This correlation would give the Jaonsár and Vindhyan systems an age corresponding at the latest to part of the Silurian system of Europe,—a correlation, so far as the Vindhyans are concerned, in accordance with that adopted by the authors of the Manual, though at variance with that suggested by Mr. Griesbach.[1] This latter, however, is even more conjectural in its basis than that which I have offered, and, moreover, does not appear to allow sufficient time for the enormous unconformity between the Vindhyans and the Gondwanas of the Peninsula.

Other systems.

As regards the remaining systems of the Lower Himalayan sequence, it is impossible to do more than guess at their ages. The central gneiss is presumably of "Archæan" age, for the Deoban limestone I can find no equivalent among the fossiliferous beds of the Central Himalayas, while the Krol limestone is probably represented by part, which part cannot be determined, of the limestones which extend from Lower Trias to Lias in Spiti and Kashmir.

General conclusions.

The general conclusion we may arrive at is that throughout the whole of the Palæozoic and Mesozoic periods the area under consideration has been alternately land and sea, and that throughout this long period there appears to have been but little disturbance of the beds, in consequence of which there is a general parallelism of dip and unconformity can, as a rule, only be determined by overlap.

[1] Rec. Geol. Surv. Ind., XIII, 88.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1888. [November.

Notes on Indian Fossil Vertebrates, *by* R. LYDEKKER, B.A., F.G.S.

1. THE ULNA OF *Hyænarctos*.

Among a small collection of bones obtained by Mr. R. D. Oldham in the Siwaliks of Kasamúri Rao, Sahâranpur district, and lately sent to me by the Director of the Survey, the only specimen of any interest is (No. H $\frac{47}{8}$) the nearly entire right ulna of one of the species of *Hyænarctos*. Of this bone the proximal extremity is represented in the accompanying woodcut (fig. 1). In regard to the generic reference, it is quite clear that this specimen does not belong to the *Felidæ*; and the only other known Siwalik carnivore of sufficient size to which it could belong is *Hyænarctos*. The specimen agrees, moreover, with the imperfect ulna in the British Museum noticed in the 'Palæontologia Indica,' ser. 10, vol. II, p. 225, which was probably associated with the type skull of *H. sivalensis*; and since it closely resembles the corresponding bone of *Amphicyon*, its reference to *Hyænarctos* may be considered certain.

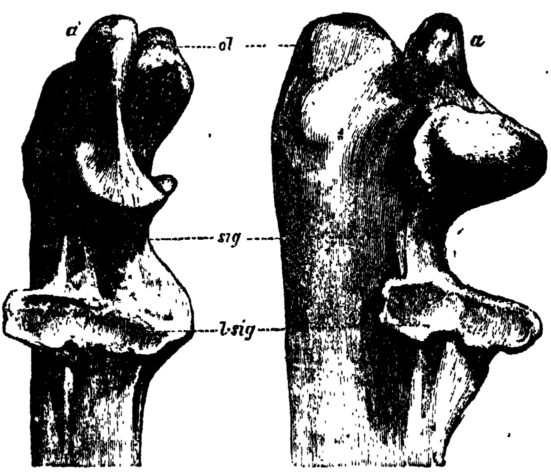


Fig. 1. Palmar and preaxial aspects of the proximal extremity of the right ulna of *Hyænarctos*; from the Siwaliks of the Sahâranpur district. ½ nat. size. *ol.*, olecranon; *a*, anterior tuberosity of do.; *sig.*, greater sigmoid cavity; *l. sig.*, lesser sigmoid cavity for head of radius.

In the above-mentioned ulna the proximal extremity is wanting; and since there is

great variation in this part among the different genera of Urso-Canoids, some important conclusions may be drawn therefrom as to the affinities of *Hyænarctos*. It will be observed from the figure that the olecranon is well developed, ascending a considerable distance above the proximal portion of the greater sigmoid cavity for the articulation of the humerus, and possessing a strongly-marked anterior tuberosity. The lesser sigmoid cavity is deeply concave, and indicates free supination of the manus. Compared with the ulna of *Amphicyon* figured by Dr. Filhol in the 'Ann. Sci. Géol.,' vol. X, pl. XIV, fig. 3, the resemblance is so close that in the absence of other evidence the two specimens might well be referred to the same genus. In the ulna of *Canis* the well-developed olecranon is retained, but the lesser sigmoid cavity becomes much flatter and less well defined in correlation with the greatly diminished power of supination of the manus. Turning, however, to the ulna of *Ursus* (fig. 2), we find a wide difference from our specimen, owing to the abortion of the olecranon and the almost total disappearance of its anterior tuberosity. A very similar condition of the olecranon obtains in the Primates, and is, I presume, connected with the power of straightening the fore arm on the upper arm.

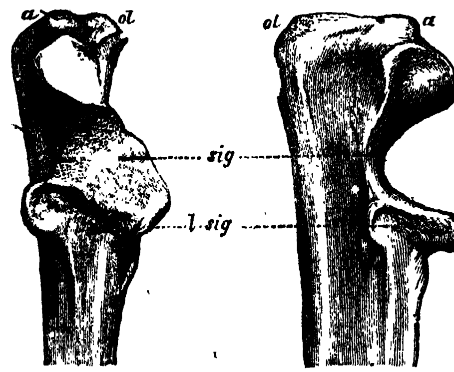


Fig. 2. Palmar and preaxial aspects of the proximal extremity of the right ulna of *Ursus arctos* : ½ nat. size. Letters, as in fig. 1.

In my description of the skull of *Hyænarctos* in the 'Palæontologia Indica' already cited, the conclusion was reached that this genus might be regarded as connecting *Amphicyon* with *Ursus* through the intervention of the American *Arctotherium*. This conclusion receives support from the present specimen, which (as is the case with the carnassial teeth) is nearer to the corresponding element of *Amphicyon* than to that of *Ursus*; and I conclude that the humerus was in all probability furnished with an epicondylar foramen, as in the former genus. In *Arctotherium*, which displays a dentition much more like that of *Ursus*, the olecranon has become aborted after the Ursine type.

Finally, I may observe that on page 239 of the above-quoted memoir I expressed an opinion that the dentition of *Hyænarctos* was more specialized than that of the Bears. This opinion I now withdraw, and, in accordance with the views of Professor Flower, I look upon the Bears as the most specialized members of this branch of the Urso Canoid stock; which have, however, to suit their fissorial and scansorial habits, retained the primitive pentedactylate and plantigrade feet.

2. *Massospondylus*, FROM THE KAROO AND GONDWANA SYSTEMS.

In my memoir on the 'Reptilia and Amphibia of the Maleri and Denwa Groups' published in the 'Palæontologia Indica,' ser. 4, vol. i, pt. 5 (1885), I described (pp. 26–29) and figured certain Reptilian remains from the Maleri beds which I regarded

as Dinosaurian; and placed in the neighbourhood of the English Triassic genus *Thecodontosaurus;* following the lead of Professor Huxley in classing the latter with *Scelidosaurus* and its allies. I thought it, however, advisable to refrain from giving a generic name. These remains comprise one extremity of the centrum of a dorsal or lumbar vertebra (pl. V, fig. 4), a caudal vertebra (*ibid.*, fig. 7), some phalangeals (pl. IV, figs. 7, 8), and teeth (pl. VI, fig. 10, and woodcut fig. 1, p. 29). The vertebræ are amphicœlous, with long, laterally-compressed centra, having oval terminal faces, and the upper surface deeply excavated by the base of the neural canal. The phalangeals resemble those of the Ornithopoda and Theropoda; while the teeth come nearest to those of the European *Thecodontosaurus* and the North American Triassic *Anchisaurus* (*Amphisaurus*); these two genera being placed by Professor Marsh in a single family of the *Theropoda* under the name of *Anchisauridæ*.

During a recent visit to the Museum of the Royal College of Surgeons I was struck with the resemblance to the above-mentioned specimens presented by a series of Reptilian bones collected many years ago from the Karoo system near the town of Harrismith, in the Drakenberg range, Basutoland. These specimens are catalogued by Sir R. Owen in the 'Catalogue of Fossil Reptilia,' pp. 97, 99 (1854), under the names of *Massospondylus* and *Pachyspondylus;* caudal vertebræ being taken as the types of the two genera. The bones are coated with a hard ferruginous matrix, and are indistinguishable as to mineralogical condition from Maleri specimens.

It will be unnecessary on this occasion to discuss the question whether there are really two genera among these South African specimens; and it will be convenient to refer to the dorsal vertebræ and limb-bones under the name of *Massospondylus*, since there is at least an equal probability of their belonging to this genus rather than to *Pachyspondylus*. The specimens comprise, in addition to the caudals, several centra of trunk vertebræ, an ilium, and numerous phalangeals of the manus and pes. In the original notice it was stated that some of these remains showed Dinosaurian affinities, but their ordinal position was left an open question.

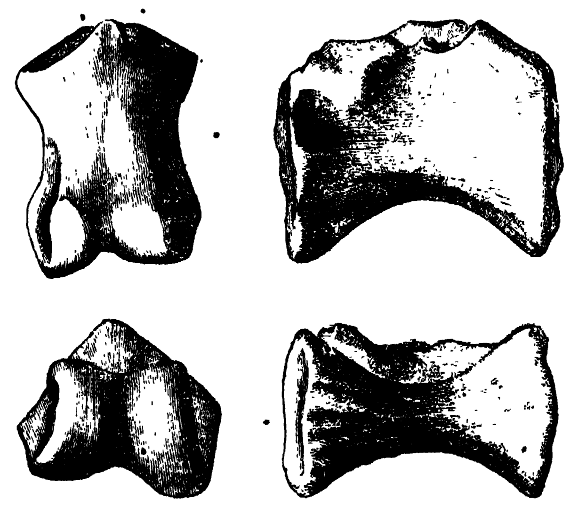


Fig. 3. Dorsal and distal aspects of a phalangeal of the manus, nat. size; and lateral and hœmal aspects of the centrum of a trunk vertebra, ½ nat. size, of *Massospondylus carinatus;* from the Karoo system of Basutoland.

With our present knowledge of the structure of the Dinosauria it is at once apparent that these African bones are referable not only to that order but to the sub-order Theropoda. Thus the ilium, which belongs to a small individual, is of the general type of that of *Megalosaurus*, although presenting well-marked generic differences. The

characteristic sharply-curved terminal phalangeals of the manus are also decisive as to the subordinal position. In the trunk vertebræ, of which one specimen (No. 336) is represented in the accompanying woodcut, the centrum is much constricted laterally and excavated inferiorly, with oval and amphicœlous terminal faces, after the manner of the dorsals of *Megalosaurus*. Certainty is added to this resemblance by the presence of a fusiform median cavity in the centrum, as is demonstrated by a transverse fracture now cemented together. One of the second or third phalangeals of the manus (No. 380) is shewn by the side of the vertebra in fig. 3.

The special interest of these specimens lies, however, in their close resemblance to the above-mentioned Dinosaurian bones from Maleri. The vertebra figured in the accompanying woodcut, except for its smaller size, cannot indeed be distinguished from the Maleri specimen shewn in pl. V, fig. 4 of my memoir; while the figured African phalangeal of the manus agrees in all respects with the larger Indian phalangeal of the pes represented in pl. IV, fig. 8. It is true, indeed, that these resemblances are insufficient to indicate with absolute certainty the generic identity of the Indian with the African form, yet when we bear in mind the occurrence of generically identical Dicynodonts in the Gondwana and Karoo systems, the extraordinary similarity to one another presented by those two series of deposits, and the absolute identity in the mineral condition of the African and Indian specimens under consideration, I venture to think that we may be justified in referring the latter to the African genus. Accepting this reference, important evidence is afforded by the Maleri teeth as to the relationship of *Massospondylus* with the *Anchisauridæ*, to which family it may, I think, be pretty safely referred. I am not, indeed, in a position to say whether the Old World genus is really distinct from *Anchisaurus;* but if the latter is unknown in Europe its appearance in India would be very unlikely. The original notice of *Massospondylus carinatus* is too incomplete to allow of the name being regarded as more than a manuscript one; and, if such a course be permissible, I would suggest that it might date from the present description, with the figured specimens as the types.

The matrix of the African specimens of *Massospondylus* being different from that in which the African Dicynodonts are found may be taken as fair evidence of a distinct geological horizon; and since the occurrence of Dicynodonts in the Panchet stage of the Gondwanas indicates the probability of these beds being the equivalents of those which yield the same family in Africa, it is probable that the Harrismith beds yielding *Massospondylus* are the equivalents of the Maleri stage, which is considerably higher than the Panchets.

In conclusion, I may express my thanks to Professor Stewart, Conservator of the Royal College of Surgeons, for permission to describe the African specimens.

Some Notes on the Geology *of the* North-West Himalayas; *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.*

SPITI.

The observations on which the following remarks are based were made during a tour, through Ladak and Kashmir, undertaken with a view to determining how far the discrepancies between the sequence of beds in Kashmir, as described by Mr. Lydekker, and that of the Simla region was real. As the country traversed has, with a small exception, already been examined cursorily by previous observers, I shall only notice those points on which I find it necessary to differ from or amplify opinions already recorded.

The first exposure of gneissose granite seen was on the road between Narkanda and Kotgarh at about one mile before the road to Kotgarh branches off from the old Hindustan and Thibet road. This exposure is apparently a continuation of the lower of the two exposures on the Hattu ridge, recorded by Colonel McMahon, but, owing to the density of the forest, the two could not be traced into continuity. Colonel McMahon has expressed an opinion, based on the microscopical characters of the rock, that these exposures must be regarded as metamorphic gneiss, not granite. I find myself unable to agree with this opinion, for not only do both bands occur among schists and bacillary quartzites undistinguishable from those of the Boileauganj Hill and like them associated with black carbonaceous slates, but in the exposure on the summit of Hattu I saw several well-defined crystals of orthoclase lying with their longer axes more or less transverse to the planes of foliation. Mineralogically the rock is a gneiss, and in the lower exposure the porphyritic crystals of felspar have lost their crystalline outline and form mere lenticular eyes, so that both macroscopically and microscopically the rock might well pass for gneiss did not its association preclude the idea.

But this loss of the characteristics of an intrusive rock is not nearly so marked as in an exposure on the old road from Kotgarh down to the Sutlej. Here, above the village of Shaot,[1] there is what looks like highly-foliated mica schist, with little or no quartz but occasional specks of felspar. For the most part the rock is very soft, but there are occasional harder bands which, owing to a larger proportion of felspar and quartz, have resisted decomposition. On breaking open a block of the micaceous rock the felspar is seen to be in larger proportion than appears on the weathered surface, as each speck is but the termination of a rod of felspathic material devoid of definite crystalline structure. The rock occurs among carbonaceous slates and quartzites of the type of the Infra Krol groups of Mr Medlicott, and can hardly be ascribed to a metamorphism of part of these beds *in situ*, while the drawing out of the felspathic material into strings is probably due to fluxion while the rock was in a plastic condition. If this conclusion be correct the rock is an extremely impure representative of the gneissose granite, several other exposures of which, all highly micaceous, though not so much so as this one, occur lower down the same spur.

[1] Situated on the spur between Súlau (Súilán) and Kété (Rita).

Along the Sutlej valley exposures of gneissose granite are common and have already been recorded by Colonel McMahon; they are all shewn to be granite by the occasional occurrence of definite crystals of orthoclase lying more or less transverse to the foliation planes. These crystals become more numerous and conspicuous towards the east; in other words the further the intrusions are traced from their eastern source the more do the originally well-formed orthoclase crystals lose their crystalline form and become degraded into rounded lumps of felspar.

Rocks of the Sutlej Valley.—With the exception of the gneissose granite, some true gneiss seen on the last two marches and the diorite intrusions described by Colonel McMahon,[1] the rocks between Kotgarh and the Wangtu bridge are of volcanic origin, carbonaceous slates, white quartzites similar to those of Bawar and other less characteristic beds belonging to the same series which I have proposed to call Carbonaceous. Two interpretations of the section have been given on different occasions by Colonel McMahon, but beyond expressing an opinion that both require extensive modification I shall add nothing to what has been written above. All conjectural interpretations of Himalayan sections, not based on extended survey, are in the last degree hazardous, especially where, as in the present case, the section is carried almost along the strike of the beds.

Central Gneiss of Wangar Valley.—I have already incidentally mentioned the occurrence of true gneiss south of the Sutlej valley, but the series is much better exposed on the ascent from Wangtu bridge to the Sutlej valley. At the bridge itself oligoclase granite is *in situ*, as has been abundantly described by previous observers, but on the ascent it soon gives way to gneiss. I have nothing here to add to the late Dr. Stoliczka's description but to say that it is most indubitably a gneiss series and as distinct as can be from the intrusive gneissose granite. Occasionally specimens are so highly granitoid that the foliation has disappeared, but the occurrence of well-defined beds, arranged parallel to each other and differing in lithological structure and mineralogical composition, shew that the series must have originated by sedimentation or some analogous process. The junction of the gneiss and slate series of the Babeh pass is marked by an intrusion of the gneissose granite; and nothing could be more distinct than the porphyritic granite devoid of stratification, with its defined crystals of felspar lying without any definite orientation, and its numerous inclusions, whether of foreign rock or formed by greater local concentration of the micaceous element on the one hand, and the distinctly stratified gneiss, often granitic, not infrequently porphyritic but with the porphyritic felspar, whether crystalline or in the form of lenticular eyes, lying parallel with the foliation, planes on the other.

Babeh Pass and Spiti section.—I have little to add to Dr. Stoliczka's description of this, and nothing to modify except as regards the lower portion.

The lowest beds, or slate group of the Babeh series, contain some bands of carbonaceous slate which render it probable that they may be brought into their present position by disturbance. The upper beds of the series, consisting of red quartzites resemble very strongly the quartzites of Chakrata, even to the occurrence of fragments of serpentinous rock and occasionally a film of serpentine on the bedding planes, as is not uncommon among the 'Lower Chakratas' of N. E. Jaonsar.

[1] Rec. G. S. of I., X, 214, *et seq.*; XII, 65, *et seq.* and 75, *et seq.*

Above these quartzites are some black carbonaceous slates, slightly schistose and shewing a sheen on the foliation surfaces, very common among the 'Infra Krols' of the Simla area. It is not impossible that the upper and lower groups of Stoliczka's Babeh series may be the same, and that instead of a regularly ascending section there is a very much compressed anticlinal. However, beyond the occurrence of black carbonaceous slates there is nothing to support the supposition; I could not recognize the slates on either side of the quartzite as belonging to the same group.

The Muth series of Stoliczka resembles nothing I am acquainted with in the Simla area. One thing I feel certain of, that it does not represent the Blaini group of Simla; the conglomerates of the Muth series are perfectly ordinary conglomerates and quite different to the very peculiar Blaini rock. According to Dr. Stoliczka there is a transition between the Muth and Babeh series, the purple (red) beds at the base of the former being said to be interbedded with the green and grey slates and quartzite at the top of the former. I do not know how far this statement rests upon a direct observation, or how far it may depend on a distant view of the cliffs overhanging the left bank of the stream.[1] If only the latter, little weight can be attached to the observation, as fallen fragments shew that ther ed colouration of the bands interbedded in the grey beds is superficial, while the colour of the lower group of the Muth series extends through the rock.

The uppermost group of speckled and white quartzites so strongly resembles some of the quartzites of the Carboniferous series of Kashmir, and in a less degree of the Carbonaceous series of the Simla area, that one may be allowed to doubt whether they should not be ascribed to the Kuling series. This would make the Muth series Carboniferous, though the obscure fossils it has yielded were regarded by Dr. Stoliczka as Silurian. As none of these were specifically determinable, perhaps too great weight should not be allowed to this opinion.

The Kuling or Carboniferous rocks are not well exposed in Spiti; its apparently capricious appearance and relations to the other sedimentary groups support the opinion, expressed by Dr. Stoliczka, that there was an unconformable break at the close of the Carboniferous period. The lithological resemblance of the beds to those of the carbonaceous series of the Simla area is striking, and at two spots in the Spiti valley a rock occurs which resembles in structure the Blaini conglomeratic slate. The first or easternmost of these is associated with beds believed by Colonel McMahon[2] to belong to the Carboniferous or Kuling group: in this I agree with him though no great certainty attaches to the identification. But in the case of the second exposure there can be no doubt whatever that the beds among which it occurs are of Kuling age.

The similarity of the rocks of the Kuling and Carbonaceous series of itself suggested to Dr. Stoliczka the probability of their being the same, and when we find beds, like the conglomeratic and carbonaceous slates, both of which, and especially the former, point to special and unusual conditions of deposition, common to the two, this suggestion acquires a degree of probability which closely approaches a certainty.

[1] Dr. Stoliczka's route lay along the right bank.
[2] Rec. G. S. of I., XII, p. 63.

Recent and Glacial Deposits of the Babeh Pass.—One of the most striking features noticeable on this route is the marked absence of distinct traces of glaciers south of the pass and their conspicuousness north of it. The valley of the Wangar is straight and open, and without interlocking spurs—a feature often regarded as characteristic of glacier action. But as the valley has been filled to some hundreds of feet with recent river gravels which have been largely re-excavated by the stream this feature is not conclusive: for once deposition begins to take place in a rocky valley the stream is no longer confined to one channel but is free to wander over the gravelly bottom of the valley and impinge on one spur after the other, gradually cutting away their extremities and so forming a straight and open valley. This may be seen everywhere in the Himalayas where a stream is flowing in a gravelly bottom; often the oldstraight valley with its floor of deposition can be traced, while at a lower level the stream flows in a narrow tortuous channel with interlocking spurs.

The mere openness of the valley is not, therefore, by itself a proof of its having been filled by a glacier. Nor are any moraines seen south of the pass, though there are several landslips which might pass for moraines. The first of these forms a pine-clad barrier stretching across the valley immediately below the summer grazing ground of Muling. In form it resembles a moraine, but it contains no fragments of the slate which forms all the hills at the head of the valley, while immediately above it is a recent landslip repeating its features on a smaller scale. This landslip, which was said to have fallen last year, extended across the river channel and evidently for a time dammed it back as the barrier has been breached, leaving a portion of the landslip separated from its source by the river channel. Although breached it has not been without influence on the river, for above it the spread-out shallow course of the stream and the partially buried trees shew that the gradient has been checked and that deposition is taking place.

Further up-stream there is again what might be mistaken for a moraine were it not that the deposit consists entirely of blocks of porphyritic granite fallen from above; while there is not a single block of the slate which commences a mile higher up and extends to the watershed.

Above Portirang, whence the track strikes up from the valley to cross the Babeh pass, there is another old landslip, and above it a plain of sand and fine gravel which seems to occupy the position of a former lakelet dammed by the landslip.

From Portirang the path ascends a steep slope of débris, and here we first come upon an indubitable moraine, for this slope is that of the moraine of a small glacier which, descending from the pass, rode out into the valley over its own moraine.

North of the pass there is a landslip just above Práda;[1] and at Práda a hummocky grass-clad surface which appears to be a moraine. Lower down, the valley broadens out, and at Baldar there is a perfectly preserved moraine stretching across the valley in a crescent, convex down-stream.

Below Baldar the bottom of the valley is occupied by river deposits of rounded

[1] This is Baldar of the map; Baldar, misprinted Balair in Dr. Stoliczka's memoir, p. 18, is further down, at the junction of the first considerable stream from the east.

gravel, but over these a glacier must have travelled, for less than a mile above Múth there are the remains of an old moraine resting on the river gravels.

We have consequently distinct traces of glaciers having extended on the north side of the pass to a distance of 3,000 feet below and 17 miles from the crest; while on the south side no certain traces can be found more than 1,000 feet below and about ½ mile from the crest.

This difference is paralleled by the present distribution of ice; south of the pass there is said to be a small glacier; I was not able to determine its extent as the whole country was covered with snow, but it cannot extend for more than a ¼ mile. To the north, on the contrary, the descent leads for over 2,000 feet and 2½ miles over the Babch glacier. The contrast is doubtless due to the fact that the waste is much less on the north than on the south side of the pass; not only from the intensity of the sunshine being less, but to a much larger extent owing to the comparative absence of rain, little of which falls north of the pass, while there is probably a much less proportional difference in the snowfall.

Recent Deposits of the Spiti Valley.—In the valley of the Spiti recent deposits are largely developed and extend high up the N. E. side of the valley. It is noteworthy that the slope of the obscure bedding in some of these shews them to be portions of talus fans which came from the S. W., so that it becomes clear that as the Spiti river excavated its course in the neighbourhood of Dhankar it worked out a channel lying S. W. of its original one.

It is evident from an examination of these deposits that the Spiti river has seen many vicissitudes and has frequently changed from erosion to deposition and *vice versâ.* At one time its valley for many a mile was occupied by a lake whose only vestiges now are whitened cliffs of fine laminated clay which can be seen at intervals from near the bridge at Mani to near Lára, a distance of 9 or 10 miles. The stuff is fine and clayey; on the surface it weathers pale yellowish-white, but inside it is of a grey colour; where not covered by rain-wash it may be seen to be finely stratified; near the sides of the valley strings of angular gravel tail off into it, while everywhere small pebbles are to be found though rarely; in composition it consists largely of finely comminuted limestone, in consequence of which it effervesces freely with acid and a large proportion is dissolved. From these facts it is not difficult to conclude that the stuff is mainly if not entirely glacier-mud which has been deposited in a lake.

LADAK AND KASHMIR.

Gneissose and Granitic Rocks of Rupshu and Ladak.—These have been referred to by both Mr. Lydekker and Dr. Stoliczka, but as neither distinguished between gneiss and granite their descriptions leave much to be desired.

The rocks on the shores of the Tso Morari are not gneiss as marked on Mr. Lydekker's map but slates mostly somewhat schistose and limestones. Among these there is an intrusion of gneissose granite which sends off many veins running through and among the slates; this is the southern of the two exposures of gneiss mentioned by Dr. Stoliczka on p. 127 of his memoir.

North of the Tso Morari the slates &c. are unconformably underlaid by a true gneiss series, distinctly stratified, with the foliation parallel to the stratification, which extends to the southern boundary of the Indus Valley Tertiaries.

The next exposure seen belonged to the Ladak range. This rock I saw on the pass between Maya and Shushul, again on the Chang La and along the north bank of the Indus from Ladak to near Nurla. Everywhere the rock was a syenite, on the Chang La micaceous, shewing no signs of stratification or foliation. Mr. Lydekker has described it to the west of Leh as having a dip to N. E.; all I could detect was a parallel system of joints dipping in that direction, but there was no division of the rock into bands differing from each other in composition. On the contrary it presents all the characters of an igneous rock, meaning thereby a rock which has solidified from a fluid condition. Inclusions of finer-grained rock differing in composition from the main mass are frequent, but besides this there are great variations in the composition of the rock: large masses of highly hornblendic rock ramify through the syenite and intrusions are frequent.

The whole mass so far as its composition goes might be intrusive, but if so the intrusion was of long pre-tertiary date, for the bottom beds of the tertiaries rest on an eroded surface of the syenite, indicating a lapse of time sufficient for the removal of the vast thickness of rock that once overlaid the syenite. Whether the latter is Archæan or no older than the granite intrusions of the outer hills I am unable to say.

The high range south of the Pangong lake, where crossed by the road from Shushal, consists of gneiss with intrusive veins of gneissose granite.

Finally the Tertiaries at Khargil rest on an unfoliated granitic rock containing hornblende, whose relation to the Tertiaries is the same as that of the Ladak range.

The Indus Valley Tertiaries.—As these have already been described by Mr. Lydekker more fully than I could do, I shall confine myself to considering the conclusions that may be drawn from them.

To begin with the serpentine rocks: both Dr. Stoliczka and Mr. Lydekker speak with uncertain voice regarding their mode of origin, but both convey the impression that they form a large intrusive mass, though in both descriptions there are not wanting indications that the authors did not altogether accept this conclusion.

I crossed these rocks once on the section from Puga to Maya and again between Leh and Kashmir. In both cases I found beds of clastic origin, ashes and agglomerates interstratified with traps. To take the first-named section: starting from Puga the first rock seen, after leaving the gneiss, is a serpentinous slate; this is succeeded by a conglomerate or breccia of slate and limestone, the fragments all flattened by pressure and traversed by an imperfect cleavage, and fine-grained laminated beds with fragments of rock included. The matrix of these rocks contains many small fragments of pyroxene. Further on the volcanic facies becomes more marked and we have tuff and ashes with dense pyroxenic traps, all of which have undergone more or less complete serpentinous change.

Where the stream bends to the east the dip of the beds, which had been northwards, changes to south but is very obscure. At the bend of the stream a bed of limestone occurs among the volcanics but is cut up by faults into small patches of a few yards across scattered up and down the hill side in a most perplexing manner, and this intense cutting up of the beds is sufficient to account for the absence of distinct and continuous bedding in the traps.

As to the interpretation of the section, it would at first appear that from Puga to the bend in the stream there was an ascending and below that a descending sec-

tion; the crystalline limestone occupying the centre of a synclinal. But lower down-stream this same limestone occurs on the hills south of the valley above the dense traps, and to judge by the fragments brought down by streams, is overlaid by beds very like those seen in contact with the gneiss.

On the section along the Kashmir road these features are not so well seen, but even there ash-beds can be found among the traps. So there can be but little doubt that we have here a true volcanic series.

I must not be misunderstood to deny the existence of intrusive rocks; I have myself seen these some miles south of Karzók on the Tso Morari and as far north as Shushal. Intrusive rocks doubtless occur among the volcanics,—indeed this is but what might be expected and may doubtless account for the ambiguity in the two published descriptions.

As to the lithology of the beds, beyond what is implied in the above passages, nothing need be added to the descriptions of Dr. Stoliczka, Mr. Lydekker, and later, of Colonel McMahon.

I must next consider the supposed evidences of glacial action exhibited by the lowermost beds in the Indus valley. As described by Mr. Lydekker the sandstones contain boulders of gneiss often several feet in diameter. "Some of the isolated boulders shew the beds of the sandstone bending down below them; and the polishing and smoothing of some of the others seems suggestive of ice action."

So far as my observations go I saw no blocks smoothed and striated in the manner characteristic of glacial action; nor did I see any case of the bedding of the sandstones being bent down under the blocks, though the bedding in their neighbourhood sometimes shewed a disturbance evidently due to eddies caused by the boulder, and except for the size of many of the blocks there is no necessity to invoke glacial action. But among these sandstones there are many thick banks of angular blocks of stone ranging to many feet across and shewing for the most part a sharp angular outline. They must consequently have been derived from the immediate neighbourhood or else transported by some agency—such as floating ice—that would not expose them to abrasion. Now in these banks only a very small proportion of the fragments consists of the syenite of the Ladak range, while the bulk of them are an intensely hard hornstone porphyry which has not been seen by me—or so far as I can find out by any other observer—in the Himalayas. It is precisely similar to the Maláni porphyries of Western Rajputana; and in Srinagur I was shewn some pieces of a similar stone said to have come from Badakshan.

Besides this indication of glacial agency there may be mentioned the presence of undecomposed felspar, doubtless derived from the crystalline rocks of the Ladak range on which the tertiary beds rest, in the sandstones, some of the beds being principally composed of it.

In the Himalayas I have not found the crystalline rocks decomposing into sand containing fragments of undecomposed felspar at lower altitudes than 14,000 feet, and the very common association of undecomposed felspar with other indications of an extreme climate justifies us in looking on it by itself, as an indication of a cold climate. In the present case independent evidence is also available, and the occurrence of a glacial epoch at the close of the Cretaceous or early in the Eocene period may be looked upon as extremely probable if not actually proved.

Original extent of the Indus Tertiaries.—Both Dr. Stoliczka and Mr. Lydekker have regarded the present extent of these beds as marking very closely their original extension, but as the evidence appears to me hardly to support this conclusion, and as the question is one that has an important bearing on the theory of the Himalayas, it will be well to enquire into the matter more fully than has yet been done.

As regards the north-eastern and north western boundaries, they most distinctly mark the original limit of the lower beds of the series, for these can be seen to abut against the syenite of the Ladak range. On the south-west the beds have suffered much disturbance and the boundary is not one of original contact, so that there is no direct proof that the Tertiaries may not have extended far to the south. Nor does it follow, because the original extension of the lower group to the northwards is closely marked by its present limits, that the upper members of a series many thousands of feet in thickness were similarly limited in their extension.

With regard to the volcanic beds there are ample indications of a much larger area having been covered by them than is now the case. Not only are intrusive masses of pyroxenic trap, evidently of the same age as the Tertiary volcanics, found as far south as the Tso Morari and as far north as Shushal, but Mr. Lydekker has recorded the occurrence of a large outlier of the tertiary traps in central Zánskár;[1] this was not examined *in situ*, and it is uncertain whether they belong to the bedded volcanic series or are intrusive. If the former, their occurrence on beds of Jurassic age, without the intervention of the lower group of the Indus Tertiaries, would point to an overlap and limitation of the series in a southerly direction. But if the Zánskár outlier is intrusive, then it is probably only the core of one of the old Tertiary volcanoes.

From the above considerations it will follow that the supposed original limitation of the Tertiaries to the narrow region they now occupy is only proved in the case of the lowest group, and then only of the north-western and north-eastern boundaries; while as regards the south-western boundary and the volcanic group and the beds above it there are distinct indications of an original greater extension, and there is only negative evidence against their having been originally continuous with the Eocene beds of Chang-chengmo and the outer Himalayas.

Origin of the Rupshu Lakes.—It has been usual, since the publication of Mr. Drew's paper, to ascribe the origin of these lakes simply to the damming of river valleys by the fans of their tributaries. The barriers now visible are certainly talus fans, and these must extend to some depth below the former water-levels of the lakes; in some cases it may be that they form the entire barrier.

Yet it is not easy to understand how a lake could be formed in this manner; it would certainly be more natural to suppose that the main stream would be able to keep its channel open. There is however one way in which these lakes might be directly formed by talus dams and yet the ultimate cause be very different. If we suppose that any portion of a river valley were elevated more rapidly than the rate of erosion of the river,—a not very difficult supposition in so rainless a country,—the barrier so raised would react up stream and cause the formation of a sloping surface of river gravels. If then for some distance the configuration of the river valley was such that but little débris was shed into it and below this region the amount of débris

[1] Mem. G. S. of I., XXII, 116.

suddenly increased, it is quite conceivable that the rock barrier lower down might prevent this being carried away as fast as it was shed and so a talus dam formed across the valley.

There is one fact about the lakes which is difficult to reconcile with the theory that they are due to talus dams formed under climatic conditions differing from the present, and that is the very various degrees of dessication they present. The Hanle lake is now quite dry.[1] The Lingzitharig lake is almost dried up, the present area of permanent salt lake being less than one tenth of the original area. The salt lake of Rupshu occupies one eighth of its original extent,[2] the Pangong lake about one half, while the Tso Morari has contracted but one fifth and now has at least four fifths of its original extent.[3] Had the lakes all been formed at one period they would hardly exhibit these extreme variations in their degree of dessication, and this renders it more probable that some explanation such as I have proposed is the true one, as this would allow of the lakes having been formed at different periods, and of their consequent varying degrees of dessication.

Before leaving this subject it may be well to suggest that the gradual and progressive drying up of Ladak appears to me to have been a direct result of the gradual elevation of the Himalayas which in course of time cut off a larger and larger proportion of the moisture coming from the South.

Lake Basin and Karewahs of Kashmir.

The only two hypotheses which appear to have been suggested with regard to the orgin of the Kashmir Valley and more especially of the Karewahs are (1) that the dam was a glacier descending into the Jhelum valley, (2) a talus fan similar to the supposed barriers of the Rupshu lakes. The more obvious hypothesis that it was a rock barrier since cut through appears to have been regarded with but little favour.

In considering this question it is necessary to bear in mind that, though the largest and best known, Kashmir is not the only alluvial valley within the limits of the Himalayas. On the contrary it may be stated as a general rule that alluvial deposits of varying extent may be found in every river valley above where it enters what can be shewn to be a region of special elevation. The only explanation of this peculiarity seems to be in the supposition that during the elevation of the Himalayas there have been times when the rocky bed of a river has been elevated more rapidly than it could erode its channel and thus a deposit formed above the barrier. A similar explanation I believe to be the true one in the case of Kashmir and the greater extent of the valley to be in part due to its drainage escaping across the junction of the Pir Panjal and Hagara systems of disturbance, a region which may well have been exposed to more repeated and extensive upheavals than other parts of the Himalayas.

The principal reason why other hypotheses have been adopted appears to be the supposed lacustrine origin of the Karewahs. This however I find to be extremely doubtful. In many places beds of indubitable lacustrine origin may be found among the Karewahs, but the bulk of them are plainly of subaerial origin; just as at the present day alluvium is being deposited subaerially over large areas in the valley,

[1] Mem. G. S. of I., V, p. 130.

[2] Drew; "Jummoo and Kashmir," p. 398.

[3] Op. cit., p. 305.

but here and there, in hollows left by irregularity of deposition of the alluvium, true lacustrine deposits are being formed. It seems probable that while nearly every part of the valley was at one time or another occupied by a sheet of water there never was at one time a lake extending over the whole area of the valley.

Geology of the road from Kashmir to Chamba.—This is the only part of my route which crossed entirely new ground and will consequently be described in greater detail than the rest.

Leaving the Noroboog valley I marched up the Rajpáran valley and crossed into the drainage area of the Wardwán by the Chingam pass. The rocks up to this belong to the "Panjal system" of Mr. Lydekker except near the pass where quartzites occur apparently belonging to the Kuling series, and about four miles west of the pass there is an exposure of pebble slate with black carbonaceous rock.

The head of the valley leading down to Shingam (Chingram) is excavated on an anticlinal. At the base are slates, and above these come quartzites interbedded with some black carbonaceous bands and volcanic beds. At one spot, in the second tributary stream flowing from the south, I was fortunate enough to obtain some fossils which have not yet been examined in detail but appear to be of Kuling age. It is noteworthy that here they occur well below the great development of the volcanic beds, unless there is a very complicated inversion on both sides of the valley of which I found no proof.

A curious feature may be observed near the head of this tributary. On the left side there is a sudden step or bank, commencing gradually and reaching a height of about six to eight feet; it runs along the hill side with a general course to W. 15° N., coinciding with the strike of the beds, but V-ing to the south in the valleys. It crosses the head of the next tributary, and in two of the minor drainage depressions which are not large enough to have a defined stream-bed, it has formed small hollows in which water appears to rest after heavy rain. On the watershed between the Shingam and Rajparan drainages it appears as a sudden step on the ridge, rendered more conspicuous by a talus bare of vegetation which contrasts strongly with the grass-clad slopes on either side.

Westwards from the ridge it can be traced as a sudden step, or elevation on the down hill side, running across an old moraine deposit which once formed the bed of a glacier, and on this there is a small pond naturally dammed by the elevation. I was not able to trace the full extent of this feature owing to clouds but it appears to vanish about ½ mile west of the watershed.

The only cause to which I can ascribe this is the actual appearance of a fault at the surface. I have already noticed a much more conspicuous instance in the hills south of the Giri valley between old Sirmur and Nahan, but it may be noticed that in the present case the fault is a normal one, *i.e.*, it hades to the downthrow, while the Sirmur fault follows the almost invariable rule of Himalayan faults and is 'reversed.' The feature I have described is of recent origin as is shewn by the little effect that denudation has had on it, as well as by the manner in which it traverses what appears to be the bed of an old glacier. The fact that it has in one place been able to form a permanent pond points to the sudden origin of the feature, which probably accompanied one of the violent earthquakes which are known to have affected Kashmir in the past.

Photo-etching. Survey of India Offices, Calcutta, January 1889

SAND-SCULPTURED QUARTZITE CONGLOMERATE, RAJPUTANA.

Descending the Shinton valley, slates continue with a high dip varying in direction between north and east, but towards Mogalmaidan they become schistose and garnetiferous, while all the streams leading down from the north contain boulders of gneissose granite.

From Mogalmaidan to Kishtwar mica and hornblende schists dip at high angles with a strike which has bent round to north and south, varying however up to 15° on either side, but usually not more than this.

Beyond Kishtwar a true gneiss series comes in suddenly, the junction with the schists being hidden by recent deposits. The gneiss has a general dip to south-west, and the Chenab flows along the strike and apparently close to the boundary between the gneiss and the overlying schists. In the Wariri valley a quantity of blue kyanite occurs in the gneiss by the road side and the same mineral is seen at intervals as far as Kandni.

Beyond Kandni the dip of the gneiss gets irregular and turns ultimately round to north-west. At the 'Khar gad,' schists come in, and no more gneiss is seen till above Nandan; on the road to Joru, a band of gneiss or gneissose granite was crossed.

The gneiss seen in the Chenab valley was the true bedded gneiss such as is seen on the Babeh pass section and not a gneissose granite. The junction with the schist series could not unfortunately be observed on a traverse, and I am at present uncertain whether there is a gradual transition or unconformable break.

In the valley crossed by the road a few miles before reaching Badrawár felspathic rock again appears underlying the schists. What was seen was all very decomposed, so its true nature was not determinable and I am not certain whether it is a true gneiss or a metamorphosed arkose rock. To a slight degree it resembled the latter, but it is altogether more probable that ~~it is~~ either a true gneiss, or gneissose granite. The dip of the beds is to north-east at 30° to 40° on the average and the whole termination of the spur is gneiss.

The rocks composing the ridge crossed between this valley and the town of Badrawár are schistose slates, so much less metamorphosed than those to the north and exhibiting so sudden a change that it is probable they are brought in by a fault.

At Badrawár innumerable blocks of gneissose granite may be seen, which have come from the west down the streams draining from the Kund Kaplas, but the ~~rocks~~ *in situ* as far as Tenála were grey slates dipping north eastwards. From Tenála on, my route has already been described by Colonel McMahon, and on a mere traverse I saw nothing of importance to add to his description.

Note on Blown-Sand Rock Sculpture; *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With one plate.)

There is a very general impression that the striated surfaces produced by blown-sand are similar to those produced by glacial action, and when pebbles

shewing what are believed to be glacial striæ were lately sent to Europe from the boulder-bearing beds at the base of the Speckled Sandstone series of the Salt Range, suggestions were hazarded that they might have been produced by the action of blown-sand, yet so far as my experience goes, and as far as I can compare it with the published accounts of the observations of others, there is no real similarity between the effects of two such different agencies.

In the Desert region between the Aravalis and the Indus there are many opportunities of studying the effect of blown-sand, and during the season of 1886-87 I was able to collect some specimens exhibiting its peculiarities. One of these is depicted in the accompanying plate.

The principal characteristic of a surface smoothed by blown-sand lies in numerous broad and shallow grooves, deepest at the end from which the wind blows and growing shallower as they advance, giving the surface an appearance of having been roughly dressed with a carpenter's gouge. The scale of these grooves varies largely: on the surface of the limestone plateau near Jessalmer they are two or three yards long and four to six inches broad, on quartzite boulders or the hard glassy sandstone which occasionally occurs they are no larger than those depicted in the plate. This form of surface does not result from want of homogeneity of the rock for it is exhibited alike by the homogeneous limestones of Jessalmer and by pure quartz pebbles,—in the latter case, however, very obscurely, as might be expected, considering that the rounded sand grains can have very little erosive action on quartz. In the specimen of grit and conglomerate drawn, there are of course variations of texture, but these do not appear to have influenced the sculpturing which traverses the matrix and the enclosed pebbles indiscriminately.

Apart from this peculiar sculpturing the nature of the polish imparted to all hard rocks and pebbles exposed to the drifting sand is peculiar; all are highly polished, and where, owing to the disintegration of a conglomerate, the ground is covered with pebbles, they glisten in the sun in a manner that makes it painful to travel over them. This polish is however very different to that of a lapidary and rather resembles what would be produced by oil or grease. The polish sometimes seen on a glaciated pebble, on the other hand, resembles that produced by a lapidary; for all the irregularities of the surface are rubbed down, while the sand-blast polishes all the little irregularities of the surface, alike on eminence and hollow.

Re-discovery of Nummulites *in* Zánskár, *by* TOM. D. LA TOUCHE, B.A., *Deputy Superintendent, Geological Survey of India.* (With one plate.)

In Vol. XXII of the Memoirs, Geological Survey of India, at page 115, under the heading 'Reputed Tertiaries in Zánskár,' mention is made of certain nummulites, said to have been obtained by Dr. T. Thomson in 1852 from the Singhe lá, on

the road between Khálsi on the Indus and Padam in Zánskár, which nummulites were described by MM. D'Archiac and Haime in 1853 as N. raymondi (*ibid.* p. 11). The writer of the Memoir goes on to say: "The majority of the rocks on the Singhe lá consist of dolomites, limestones, and slates of mesozoic age; and as tertiary rocks have not been detected among them, the reputed origin of these nummulites must be regarded as open to a very strong element of doubt;" and suggests that they may have been obtained from a pass with a similar name, the Shingo lá, between Leh and Skiu, on which nummulitic rocks are plentiful (*ibid.*, p. 107) though, "as Dr. Thomson did not apparently traverse this route, it seems doubtful if this solution of the difficulty can be admitted."

Having recently had occasion to cross the Singhe lá (Singala of Quarter Sheet, 45 S.W. of the Atlas of India, in approximate Lat. 33° 58′ N., Long. 76° 58′ E.), I made a search for these nummulites, and was fortunate enough to find them, thus confirming the accuracy of Dr. Thomson's statement. Moreover, I was able (the pass and surrounding hills being almost free from snow) to trace the fragments of rock in which the fossils occur on the pass to their source, and to make some observations on the relations of the nummuliferous rocks to the underlying mesozoics.

I first came upon the nummulites at Linshot, a village at an altitude of 12,850 feet, lying on the southern slopes of the range crossed by the Singhe lá, and about 5½ miles to the west of the pass. Here they occur in numerous large boulders of limestone, embedded in the drift with which the valley is partially filled. Some of these boulders are of very large size, one measuring 40 feet by 20 feet in diameter, and are generally crowded with nummulites. They have evidently been carried down from above the precipitous scarp, north of the village, probably by a glacier, though at the present day there are none on the southern side of this range. The rock containing the nummulites is a very dark grey limestone, weathering to a sooty black colour, and giving a strong fetid odour when struck or broken; it is traversed by numerous thin veins of calcite.

Between Linshot and the Singhe lá fragments of the same limestone, filled with nummulites, are very numerous in the talus along the foot of the scarp to the north, especially in the valley in which the village of Chunpa-do-Goma is situated, where the talus is almost entirely composed of them. Blocks of grey quartzite from the underlying mesozoics, forming the base of the scarp, are also very common. Fragments of the nummulitic limestones continue to be found across the Singhe lá in the talus from the cliffs to the west of the pass, but none in that on the east; and to the north as far as the large side stream, joining the main valley about half-way between the pass and Photoksar. This stream drains the northern side of the range between the Singhe lá and Linshot. Further north than this, as far as the Spangthang valley above Honupatta, west of the Sirsa lá (Sirsirla), beyond which I did not go, I could find no trace of the nummulites.

The rocks from which these fragments have been derived thus appear to be confined to the higher portion of the range immediately west of the Singhe lá. Owing to want of time, I was able to ascend the range at only one point, *viz.*, to the peak marked Z⁴ on the map; here, at an altitude of about 18,500 feet[1] at the base of

[1] Water boiled at 179·9° F. and on the pass (16,601 feet according to the map) at 183·3° F, a difference of 3·4°, which corresponds to about 1,900 feet difference in altitude.

two precipitously-scarped masses, rising to 500 or 600 feet higher, and forming the summit of the peak, I found nummulites *in situ*, and numerous fragments crowded with them fallen from the cliffs above. These two masses are built up of layers, from a few inches to over a foot in thickness, of the same black fetid limestone that is found in fragments in the talus below containing nummulites; the beds dip inwards from the north-east and south-west respectively at an angle of about 20°, forming a shallow synclinal with its axis directed downwards towards the south-east, so that the same limestones occur at a much lower level than in the peak, at the top of the scarp running west from the pass towards Linshot.

It was difficult to make out the relations of the nummulitic limestones with the underlying rocks, owing to the manner in which the hill-sides below the peak are smothered in talus, outcrops of the rocks beneath only showing through in detached patches; and this difficulty was increased by the sharp folding which the whole of the rocks have undergone. The limestones, however, appear to rest conformably on thick beds of grey quartzite, which in turn are underlaid by shales forming the pass itself. To the east succeed mesozoic limestones and slates, much folded and inverted, so that at the pass they appear to be resting on the shales. These relations I have attempted to shew in the accompanying section, but am not inclined to guarantee its accuracy in every detail.

The apparent conformity between the nummulitic limestone and the quartzite may have been superinduced by folding subsequent to the deposition of the tertiaries, for in the Indus valley the nummuliferous beds occur in the higher zones of the series, and there are indications of an overlap on the southern border of that area (Mem. G. S. of I., Vol. XXII, pp. 107 and 110).

It is thus proved beyond doubt that in middle eocene times the southern shore line of the tertiary sea (occupying what is now the Indus valley) did run out far to the south, as Mr. Lydekker supposes may have been the case (*ibid.*, p. 120), and included the Singhe lá. How much further to the south this sea extended there is no evidence to shew, as no nummulites have yet been found on any of the passes between the Singhe lá and the great range south of Zánskár; but the absence of conglomerates, such as are found in the Indus valley below the nummulitic beds, beneath the limestones of peak Z[1], would seem to shew that the shore-line was at a considerable distance. That it was not connected in this direction with the sea occupying the basin of the outer hills, seems fairly certain, for in the lower Chenab valley, where two large inliers of Zánskár rocks occur, Murree sandstones are found immediately in contact with the mesozoics of the upper and nearer inlier, while in the lower and more distant one nummulitic limestones intervene, thus indicating a shore-line to the north in that area in middle eocene times (*ibid.*, p. 92).

This confirmation of Dr. Thomson's discovery affords further evidence of the enormous earth movements that have taken place in the north-west Himalayan area since early tertiary times, whereby marine strata have been elevated more than 18,500 feet above the present sea-level. As far as I am aware, this is the greatest altitude at which marine fossils have hitherto been obtained *in situ*.

Notes on some Mica-traps from Barakar and Raniganj, *by* PRAMATHA NATH BOSE, B.SC. (Lond.), F.G.S., *Deputy Superintendent, Geological Survey of India.*

The specimens described below were collected during a short excursion with the Director to Barakar and Raniganj towards the end of last August. The time at our disposal was too short and the weather too unpropitious for a systematic study of these highly interesting rocks; and my only reasons for publishing the following rough notes, based on three specimens, all more or less decomposed, are the scant attention which their petrography has received hitherto, and the possibility of its not receiving further attention at least in the immediate future. Dr. Blanford described them twenty-eight years ago in the following terms[1]:—

"The trap forming the various dykes differs greatly in mineral character. It is generally more or less decomposed, and frequently contains a whitish micaceous mineral, somewhat resembling margarodite in little rounded masses. In many cases it contains black mica."

And this is, I believe, the only description we have of the rocks.

The mode of occurrence of the mica traps, and their probable age, have been discussed by Dr. Blanford.[2] They occur as dykes and intrusive sheets, altering the rocks in contact, and often ramifying through the coal. The action of contact metamorphism on the coal has almost invariably resulted in the production of a columnar structure in it. The columns are usually hexagonal, and invariably perpendicular to the direction of the dykes and sheets. Sometimes they radiate from a central core composed of the intrusive rock. Some beautiful examples of the radiating arrangement were seen at the Laikdih quarries near Barakar. The contact coal has been hardened, and is left in the pits and quarries, being considered worthless as fuel

The following assays of two specimens of contact, columnar coal, made by Mr. Hira Lal in the Survey laboratory, will shew their composition.

An analysis of a good sample of the normal Barakar coal is also given for the sake of comparison.

	Columnar coal		Normal coal
	No. 1.	No. 2.	
Moisture	3·38	2·98	2·48
Volatile Matter (exclusive of moisture) . .	9·02	7·02	28·72
Fixed Carbon	68·60	78·60	60·20
Ash	19·00	11·40	8·60
	100·00	100·00	100·00

[1] Mem., G. S. I., Vol. III, p 142.

[2] Op. cit., pp. 141, &c.

The contact coal burns very slowly. It is not, as has been observed above, raised at present.

The dykes and intrusive sheets are, as observed by Dr. Blanford, "almost confined to the Lower Damadas. A few instances, however, occur in the Raniganj Series." The specimens from the Raniganj mine described below are from dykes which have intruded through the latter.

With regard to the geological age, Dr. Blanford saw "good reason for supposing that these intrusions may have been contemporaneous with the great volcanic outbursts, of which evidence exists in the Rajmahal hills;" and the balance of probabilities appeared to him to be in favour of their being of Rajmahal (Upper Gondwana) age.[1]

The intrusions from which the following specimens were obtained are all very small, not exceeding six feet across.

As far as I am aware, Mica-traps have not been described from any other part of India. They are found intrusive in the older Palæozoic rocks in England (Westmorland and Yorkshire), in the Southern Uplands of Scotland, and in several localities in Ireland. They are also met with in the Channel Islands, Saxony, the Vosges Mountains, Baden, North-Western and West Central France, and in the Pyrenees.[2]

No. $\frac{8}{234}$ (Laikdih quarry, near Barakar), sp. gr. 2·77. Grayish rock with abundant flakes of biotite visible macroscopically; effervesces with hydrochloric acid. Fracture, uneven.

Under the microscope, the ground-mass is found to be microcrystalline. There are abundant rod-like, translucent microlites, some of which probably belong to plagioclase. There is also some apatite. Minute specks of viridite abound; and some cloudy dark-brown, opaque specks and patches (decomposed mica and ferrite), and a little magnetite also occur. There are, besides, irregular, nebulous, finelv grenular, greyish patches which shew strong double refraction, observable with the analyser alone. Some of these patches occur in association with secondary quartz presently to be mentioned. From their behaviour, they appear to me to consist of calcareous matter—the result, in all likelihood, of decomposition.

There are, in the ground-mass, polygonal or rounded spaces, in which shadowy outlines are discernible in transmitted light; the finely granular substance just mentioned bays into some: and magnetite is sometimes found enclosed. With polarised light some of these spaces are clearly seen to be filled with quartz (secondary), exhibiting a mosaic play of colours, and others with a zeolite shewing beautiful radiating structure. The two (quartz and zeolite) are in some cases associated together.

Some of the biotite crystals are large, which are visible macroscopically, but the majority are minute, visible only under the microscope. They exhibit strong dichroism. The larger crystals have frayed edges.

There is no well-developed felspar, nor is any pyroxene or amphibole visible.

[1] Op. cit., pp. 144-145. Colonel McMahon, from a lithological study of the Deccan and the Rajmahal traps, suggests the possibility of their being contemporaneous (Rec., G. S. I., Vol. XX, p. 110).

[2] Bonney, Q. J. G. S., Vol. XXXV, p. 165.

If the felspar microlites mentioned above really belong to plagioclase, the rock may be called *kersantite*. There is present 48·48 per cent. of silica according to an analysis made by Mr. T. R. Blyth in the Survey laboratory.

No. $\frac{8}{283}$ (Raniganj Mine). Sp. gr. 2·45. Greyish-green compact rock; effervesces, but very slightly, with hydrochloric acid. No crystals are visible macroscopically.

Under the microscope the ground-mass is seen to be microcrystalline. Minute crystals of biotite are very plentiful. It is the predominant mineral, as in the last specimen. There are some lath-shaped, badly-developed crystals of plagioclase. They occur as single individuals, and exhibit no twinning. A few crystals of hornblende occur, which shew characteristic cleavage, and marked pleochroism with polarised light. In these a granular or fibrous greenish decomposition-product sometimes appears. It is probably identical with a similar mineral which is rather abundant and which has, as a rule, a rather well-defined contour. If so, there can be no doubt that this mineral is the result of decomposition of the hornblende. With a single Nicol, the mineral in question shews very feeble dichroism, or none at all; in all probability it is chlorite. Greyish cloudy patches similar to those which have been described as occurring in the last specimen occur, but are not so abundant. Sometimes they shade off into the greenish decomposition-product just mentioned There is a little magnetite. The percentage of silica present in the rock, determined by Mr. Blyth in the Survey laboratory, is 51·68.

The rock may be called *kersantite*, if the presence of hornblende be a sufficient character to distinguish it from the last specimen.

No. $\frac{8}{282}$ (Raniganj Mine). A greyish-brown, mottled, vesicular rock. No crystals are visible with the unassisted eye.

Under the microscope, the ground-mass is seen to be microcrystalline. It is crowded with minute, badly-developed crystals of biotite. There are some long lath-shaped crystals of plagioclase, all of which appear to occur as single individuals, as in the last specimen. Greenish specks and patches abound, as in the last specimen, but no hornblende is observable. There is a little magnetite and some secondary quartz. The percentage of silica present in the rock, determined by Mr. Blyth in the Survey laboratory, is 57·88.

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